

San Juan 8-hr Ozone EAC Study: Model Performance and Future Year Ozone Levels

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Overview of Presentation

- Study Elements
- Photochemical Modeling System
- Base Case Performance for Four Episodes
- Future (2007) Baseline 8-hr Ozone Levels
- 8-hr Ozone Attainment Demonstration Findings
- Next Steps—Scenario Modeling
- Future Opportunities for Refinement

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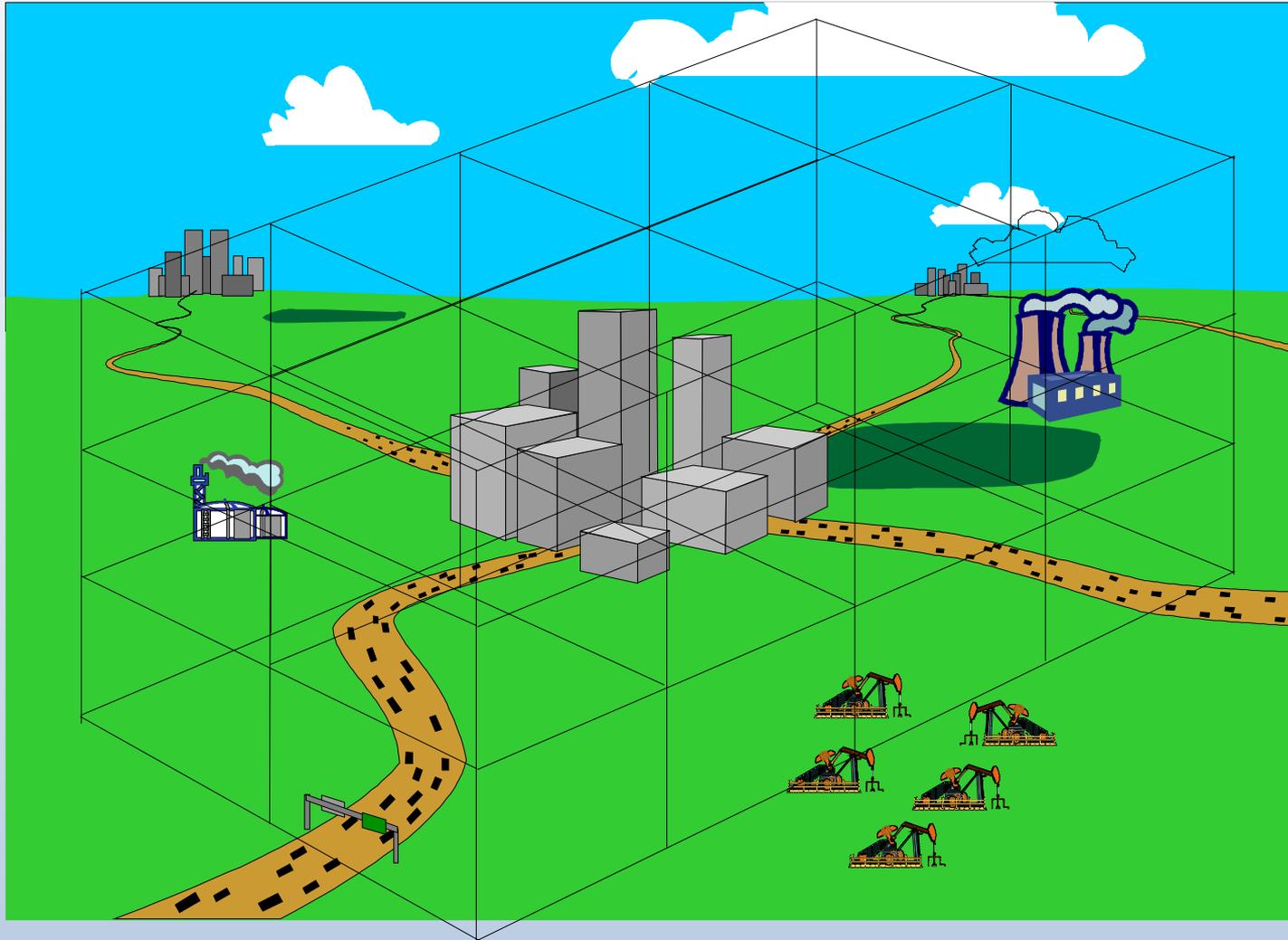
ENVIRON Offices: Novato, CA

Study Elements

- **Conceptual Model and Episode Selection**
- **8-hr Ozone Modeling Protocol**
- **Meteorological Data Bases & Modeling Report**
- **Base Year (2002) Emissions Inventory Report**
- **Future Year (2007) Emissions Inventory Report**
- **Base Year Model Performance Evaluation Report**
- **Future Year (2007) Baseline Modeling Report**

- **Year 2007 Maintenance for Growth Modeling Report**
- **Year 2007 Strategy Modeling Report**

Modeling System Set-Up



Location of Ozone Monitors

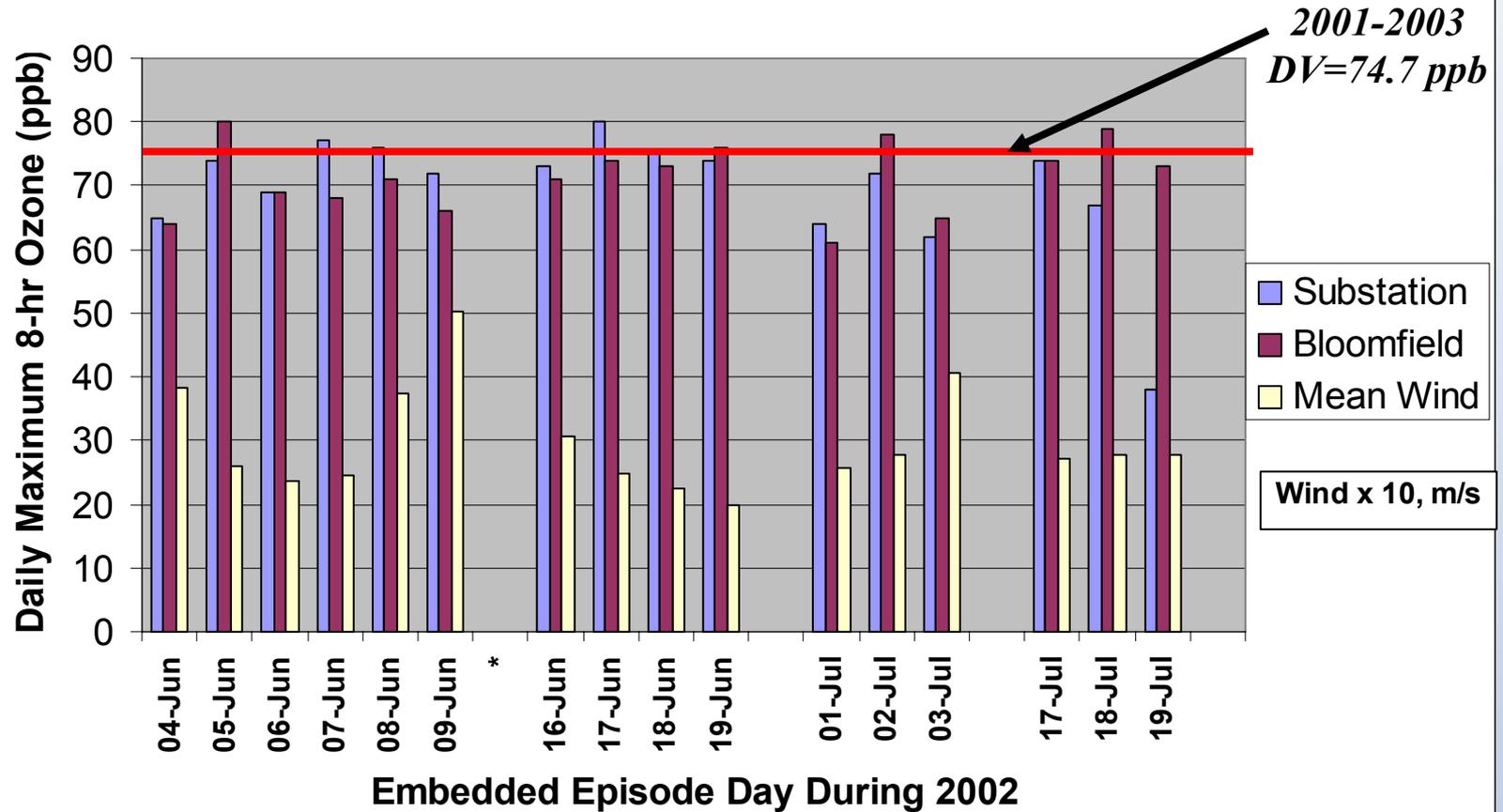


San Juan 8-hr Ozone Modeling Episodes

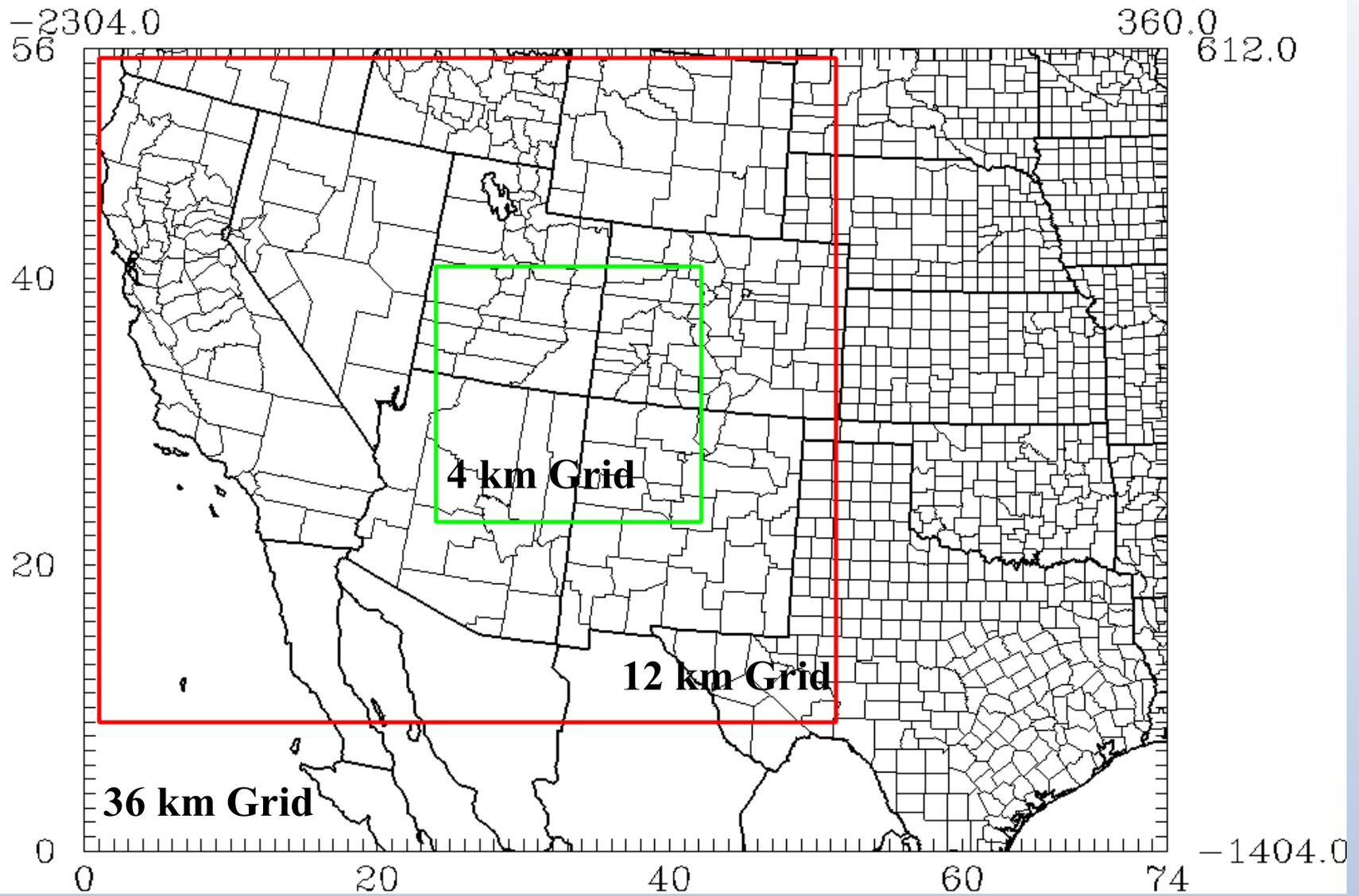
- Summer 2002 Regional Study Period
 - ▶ 3 June – 19 July 2002
- Embedded Ozone Episodes
 - ▶ 4-8 June 2003
 - ▶ 16-19 June 2002
 - ▶ 30 Jun-2 July 2002
 - ▶ 17-18 July 2002

Daily Maximum 8-hr Ozone

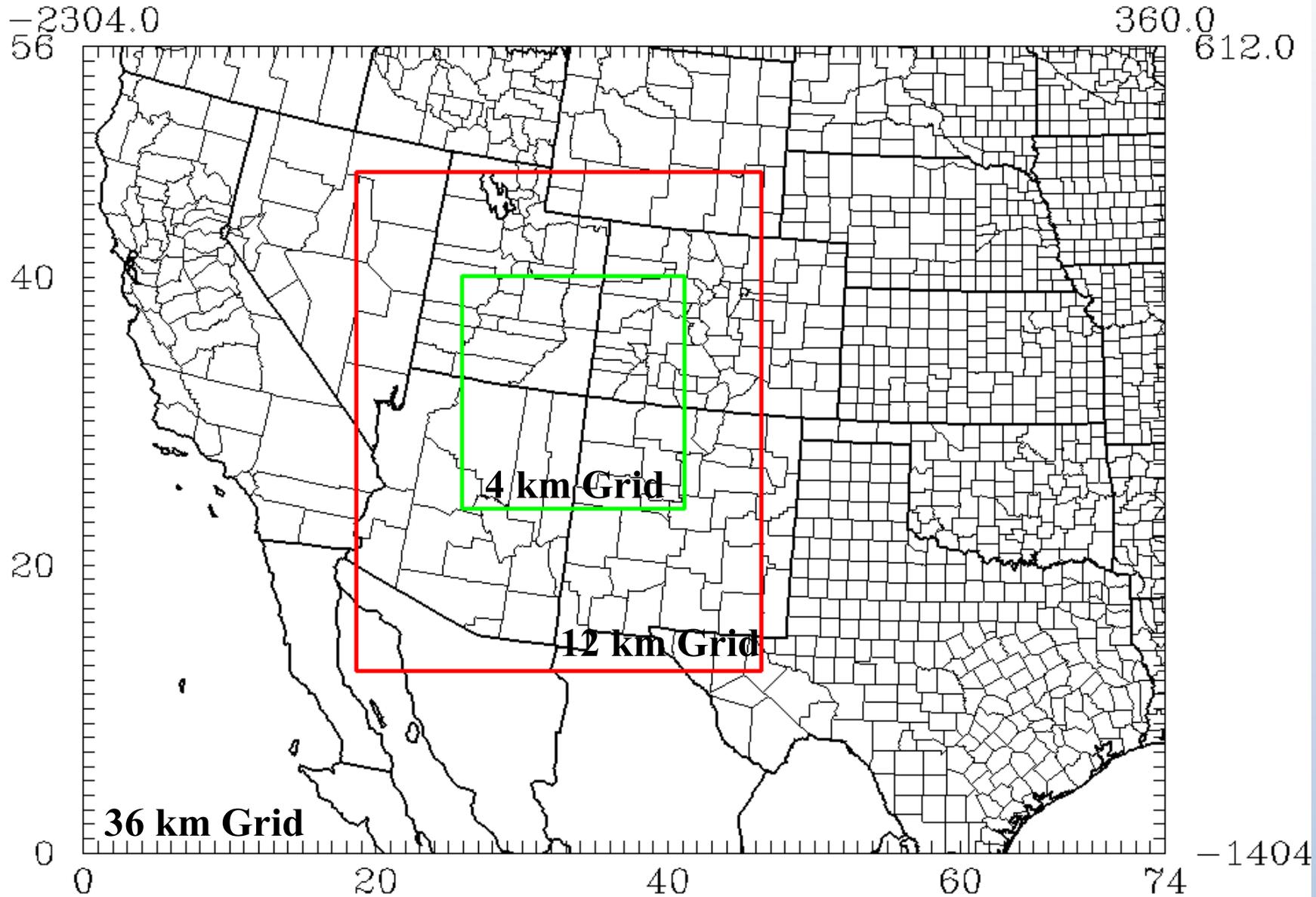
Maximum 8-hr Ozone For Each Embedded Episode



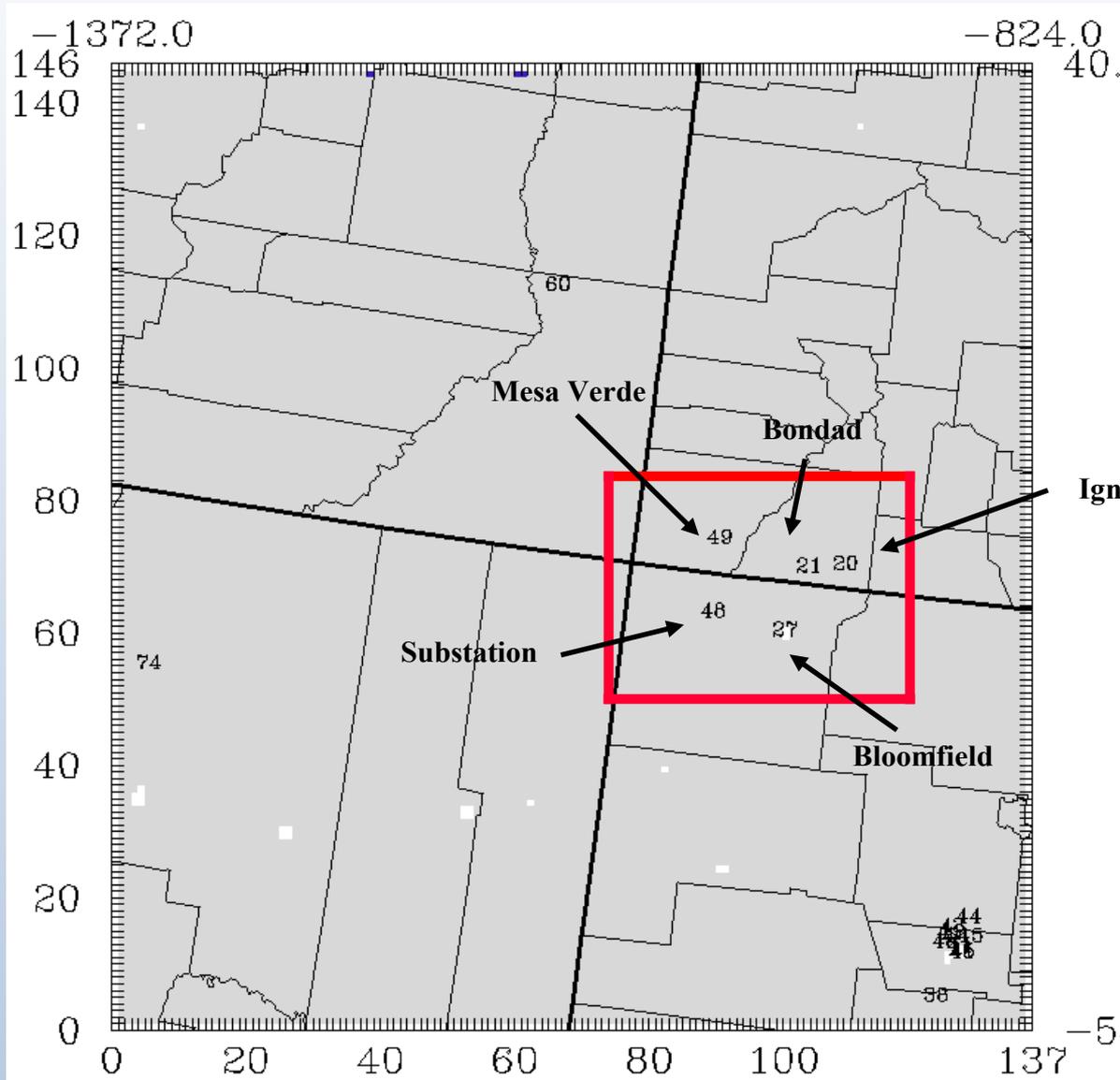
San Juan EAC Meteorological Modeling Domain



Air Quality Modeling Domain



Attainment Analysis Region



Model Selection

- **MM5 (ver 3.6)**
 - ▶ Developed by Penn State University & National Center for Atmospheric Research (since mid-1970s)
 - ▶ Successfully used in 1-hr and 8-hr Ozone SIP modeling in many other areas
 - ▶ State-of-Science, two-way grid nesting, publicly available with no restriction

- **Emissions Processing System (EPS2x)**
 - ▶ Used in many SIPs, moderate computer run time requirements
 - ▶ Well tested, straight forward to use, has good QA/QC routines

- **CAMx (ver 4.03)**
 - ▶ State-of-science ‘One Atmosphere’ ozone/PM/regional haze model
 - ▶ Employs two-way nesting, newly-developed “probing tools”
 - ▶ Used for several 8-hr EAC’s and O₃ SIPs

EPS2x Model Configuration: Base Year

Table 1. Emissions Model Configuration for the San Juan 8-hr Ozone Modeling Episodes: Base Year

Emissions Component	Configuration	Details
Emissions Processing Model	EPA2x, GloBEIS (3.1)	
Horizontal Grid Mesh	36/12/4 km	
36 km grid	165 x 129 cells	
12 km grid	151 x 139 cells	
4 km grid	163 x 160 cells	
Area Source Emissions	NM: EPA NEI99 Version 2 CDPHE Emissions Data Other States: EPA NEI99 Version 2	
On-Road Mobile Sources	NM: EPA NEI99 Version 2 CO: CDPHE Data (except Denver) Other States: EPA NEI99 Version 2	MOBILE6 used; No local transportation model data available CDPHE link-based, MOBILE6 used in Denver EMFAC2002 used in California; MOBILE6 used elsewhere
Point Sources	NM: NMED Point Source Data CO: CDPHE Data Other States: EPA NEI99 Version 2	Four Corners Area of NM, EPANEI Version 2 used elsewhere
Off-Road Mobile Sources	NM: EPA NEI99 Version 2 CO: CDPHE Data Other States: EPA NEI99 Version 2	
Biogenic Sources	Entire Domain	GloBEIS3 with BELDS3 LULC data
Oil & Gas	NM: NMOGA Data CO: Other States: EPA NEI99 Version 2	NMOGA unpermitted data base Included in Point Source Inventory Included in Point Source Inventory
Temporal Adjustments	Seasonal, day, hour	Depends upon category
Chemical Speciation	CB4 Chemical Speciation	Standard splitting factors for VOC & NOx sources used
Gridding	Spatial Surrogates Used	Land use, population, housing, etc from EPA datasets
Growth and Controls	Largely Contained in NEI99	Growth & control modules in EPS2x used
Quality Assurance	QA Tools in EPS2x	Independent QA with AG's MAPS Evaluation Software
Simulation Periods		
Episode 1: 4-9 June '02		
Episode 2: 16-19 June '02		
Episode 3: 30 June-3 July '02		
Episode 4: 16-19 July '02		

EPS2x Model Configuration: 2007

Table 4. Future Year (2007) Emissions Inventory Development for the San Juan 8-hr Ozone Modeling Episodes.

Emissions Component	Configuration	Inventory Future Year Projection Details
Emissions Processing Model	EPA2x, GloBEIS (3.1)	
Horizontal Grid Mesh	36/12/4 km	
36 km grid	165 x 129 cells	
12 km grid	151 x 139 cells	
4 km grid	163 x 160 cells	
Area Source Emissions	NM: EPA's 2007 HDD Inventory CDPHE Emissions Data Other States: EPA's 2007 HDD Inventory	
On-Road Mobile Sources	NM: MOBILE6.2 by county for 2007 typical summer day CO: CDPHE Data (except Denver) Other States: MOBILE6.2 by county for 2007 typical summer day	MOBILE6 used; No local transportation model data available CDPHE link-based, MOBILE6 used in Denver MOBILE6 used
Point Sources	NM: EPA's 2007 HDD Inventory CO: CDPHE Data Other States: EPA's 2007 HDD Inventory	Emission Estimates for MUSTANG plant provided by NMED
Off-Road Mobile Sources	NM: NONROAD2002 w/ EPA defaults CO: CDPHE Data Other States: NONROAD2002 w/ EPA defaults	nonNR sources from EPA's 2007 HDD Inventory (locomotives, airports, commercial marine) nonNR sources from EPA's 2007 HDD Inventory (locomotives, airports, commercial marine)
Biogenic Sources	Entire Domain	GloBEIS3 with BELDS3 LULC data
Oil & Gas	NM: NMOGA Data CO: CDPHE Data Other States: EPA's 2007 HDD Inventory	NMOGA unpermitted data base Included in Point Source Inventory Included in Point Source Inventory
Temporal Adjustments	Seasonal, day, hour	Depends upon category
Chemical Speciation	CB4 Chemical Speciation	Standard splitting factors for VOC & NOx sources used
Gridding	Spatial Surrogates Used	Land use, population, housing, etc from EPA datasets
Growth and Controls	Largely Contained in NEI99	Growth & control modules in EPS2x used
Quality Assurance	QA Tools in EPS2x	Independent QA with AG's MAPS Evaluation Software
Simulation Periods		
Episode 1: 4-9 June '02		
Episode 2: 16-19 June '02		
Episode 3: 30 June-3 July '02		
Episode 4: 16-19 July '02		

MM5 Model Configuration

Table 2. MM5 Configuration for the San Juan Modeling Episodes		
Blackadar.dry.uni		
Science Options	Configuration	Details
Model Code	MM5 version 3.6 (MPP)	Grell et al., 1994
Horizontal Grid Mesh	36/12/4 km	
36 km grid	165 x 129 cells	
12 km grid	151 x 139 cells	
4 km grid	163 x 160 cells	
Vertical Grid Mesh	34 layers	Vertically varying
Grid Interaction	No Feedback	IFEED=0
Initialization	Eta first guess fields/LittleR	
Boundary Conditions	Eta first guess fields/LittleR	
Microphysics	Simple Ice	Look up table
Cumulus Scheme	Kain-Fritsch 2	On 36/12 Grids
Planetary Boundary Layer	Blackadar PBL	
Radiation	RRTM	
Vegetation Data	USGS	24 Category Scheme
Land Surface Model	5 Layer	5 Layer soil model
Shallow Convection	None	
Sea Surface Temperature	Eta Skin	Spatially varying
Thermal Roughness	Garratt	
Snow Cover Effects	None	
4D Data Assimilation	Analysis Nudging on 36/12 only	No FDDA in 4 km domain
Integration Time Step	90 seconds	
Simulation Periods		
Episode 1: 4-9 June '02	3 Jun 12Z - 9 Jun 12Z	
Episode 2: 16-19 June '02	15 Jun 12Z - 20 Jun 12Z	
Episode 3: 30 June-3 July '02	29 Jun 12Z - 3 Jul 12Z	
Episode 4: 16-19 July '02	15 Jul 12Z - 19 Jul 12Z	
Platform	Athlon MP 2600+	
Run-Time	50% Real	

CAMx Model Configuration

Table 3. CAMx Configuration for the San Juan Modeling Episodes.		
Science Options	Configuration	Details
Model Code	CAMx 4.03	ENVIRON (2003)
Horizontal Grid Mesh	36/12/4 km	
36 km grid	74 x 56 cells	
12 km grid	83 x 104 cells	
4 km grid	137 x 146 cells	
Vertical Grid Mesh	21 Layers	First 17 layers sync'd w/ MM5
Grid Interaction	One-Way Nesting	
Initialization	48 hrs full spin-up	
Boundary Conditions	GEOS-CHEM/Denver EAC	
Baseline Emissions	ENVIRON Base A	Used MM5 Meteorology
Chemistry	CBM-IV	with Isoprene updates
PBL Patch	Kv_min=1.0	
Vertical Eddy Diffusivity	O'Brien '70	
Deposition	Wesley	
Advection Scheme	PPM	
Simulation Periods		
Episode 1: 4-8 June '02		
Episode 2: 16-19 June '02		
Episode 3: 30 June-2 July '02		
Episode 4: 16-18 July '02		
Platform	Athlon MP 2600+	
Run-Time (Episode 1)	4 x real	Dual Processor (OMP)

CAMx Final Base Cases

- Refined oil & gas emissions (from NMOGA)
- Lateral BCs consistent with Denver EAC
- Top BCs from 3-D global chemical transport model (GEOS-CHEM, Martin and Jacob, 2003, JGR 108, D17, pg.4537)
- $K_z = 1.0 \text{ m}^2/\text{s}$ min diffusivity treatment

Lateral Boundary Conditions: (consistent with Denver EAC Modeling)

Species	Eastern and Northern Boundaries below 1700 m (ppb)	Southern Boundary Below 1700 m (ppb)	Western Boundary and Above 1700 m (ppb)
O3	40.0	40.0	40.0
NO	0.1	0.1	0.1
NO2	1.0	1.0	1.0
CO	200.0	200.0	100.0
PAR	14.9	14.9	14.9
HCHO	2.1	2.1	0.05
ETH	0.51	0.51	0.15
ALD2	0.555	0.555	0.05
TOL	0.18	0.18	0.0786
PAN	0.1	0.1	0.1
HNO2	0.001	0.001	0.001
HNO3	3.0	3.0	1.0
H2O2	3.0	3.0	1.0
OLE	0.3	0.3	0.056
XYL	0.0975	0.0975	0.0688
ISOP	3.6	0.1	0.001
MEOH	8.5	0.001	0.001
ETOH	1.1	0.001	0.001
Total NOx	1.1	1.1	1.1
Total VOC (ppbC)	50.5	22.3	9.3

Top Boundary Conditions:

(consistent with GEOS-CHEM Global Chemistry Modeling)

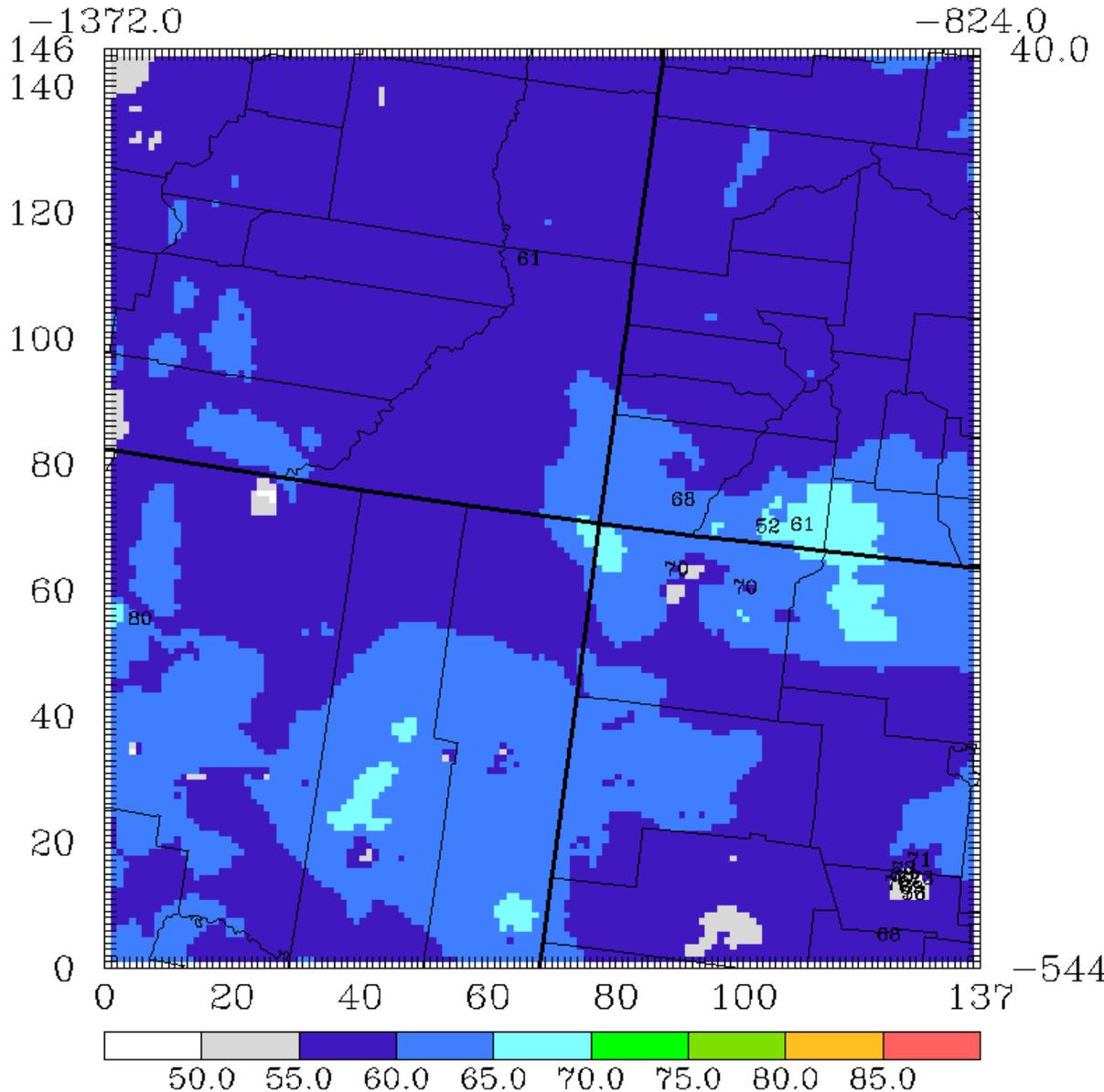
Table 1. Top Concentration BCs for San Juan Ozone Episodes.

Species	Conc (ppb)	Species	Conc (ppb)	Species	Conc (ppb)
NO	0.001132	PNA	0.002902	CG2	0.00173
NO2	0.0005182	PAN	0.08779	CG3	0.0004481
NXOY	0.0004602	CO	64.59	CG4	0.01154
O3	61.4	HONO	0.000006343	PNO3	2.461
FORM	0.06908	H2O2	0.7944	POA	4.29
ALD2	0.02536	HNO3	0.123	PEC	1.12
ETH	0.001219	NTR	0.06421	PSO4	86.67
OLE	0.0009171	SO2	0.008489	FCRS	5.156
PAR	2.888	SULF	0.00003696	CCRS	8.488
TOL	0.001637	ISOP	0.0006887	PH2O	18.24
XYL	0.0001523	OLE2	0.0000291	PCL	1.821E-23
CRES	0.0004455	NH3	2.019E-10	NA	1.181E-23
MGLY	0.0003117	ISPD	0.006533	PNH4	10.48
OPEN	0.00003109	CG1	0.0006067		

CAMx 1-hr Ozone Evaluation

- Follow EPA 1-hr Ozone Modeling Guidance Evaluation Procedures
 - ▶ Graphical Performance
 - Spatial Maps of Predictions and Observations
 - Scatter and Q-Q Plots
 - Time Series Plots
 - ▶ Ozone Metrics
 - Unpaired Peak Prediction Accuracy
 - Mean Normalized Bias
 - Mean Normalized Gross Error
- Primary Evaluation Focus on Ozone
 - ▶ Very limited NO and NO_x measurements
 - ▶ No VOC or other indicator species measurements

Daily Maximum 8-hr Ozone on 6 June '02

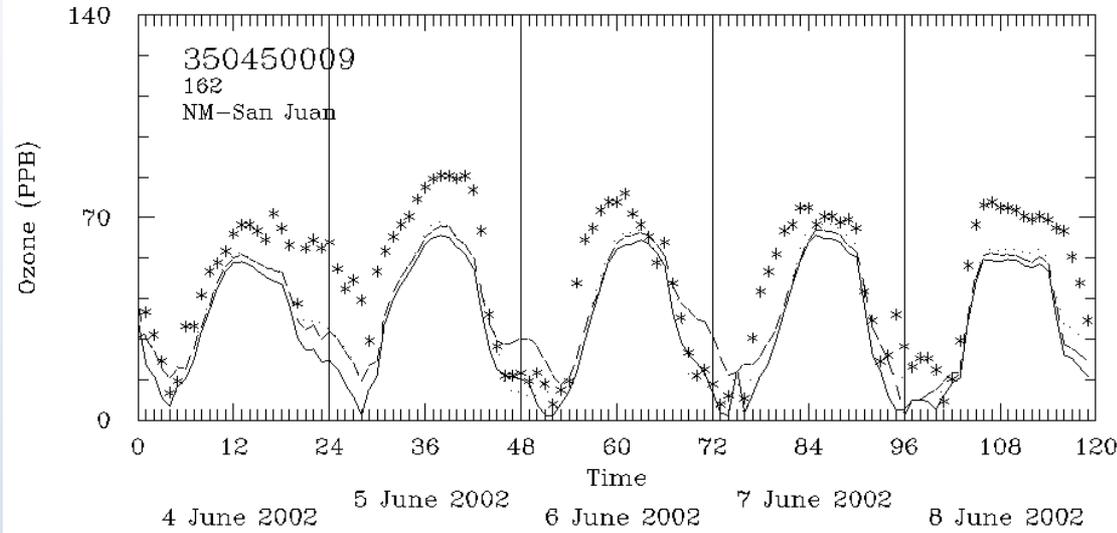


8-hr Ozone Predictions Derived from on 1-hr CAMx modeling results:

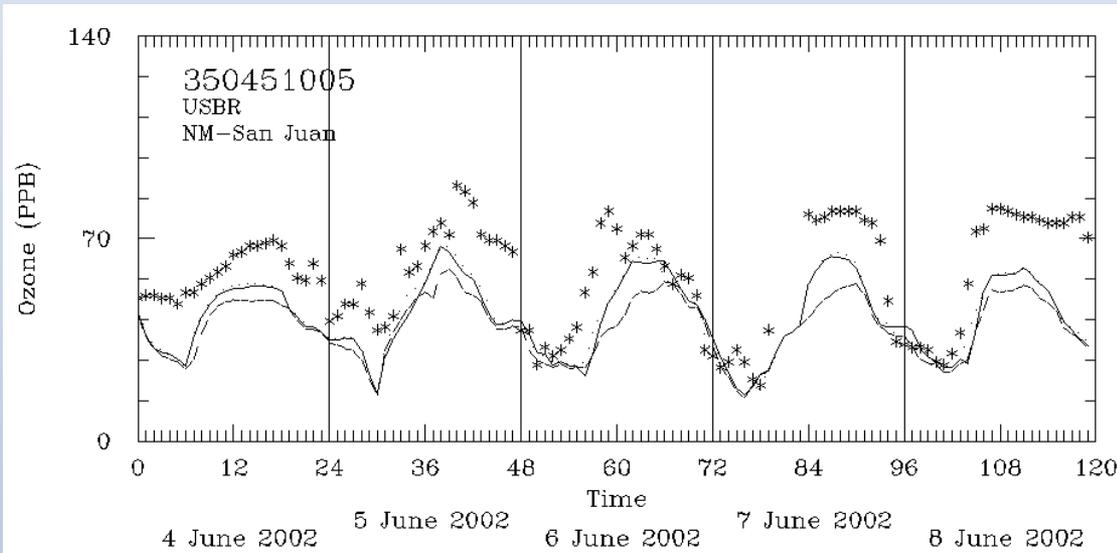
Basic model output consists of sequence of 1-hr concentration fields for ozone, NO, NO₂, VOC, etc.

1-hr Ozone Time Series for Episode 1: 4 km Domain

Bloomfield:

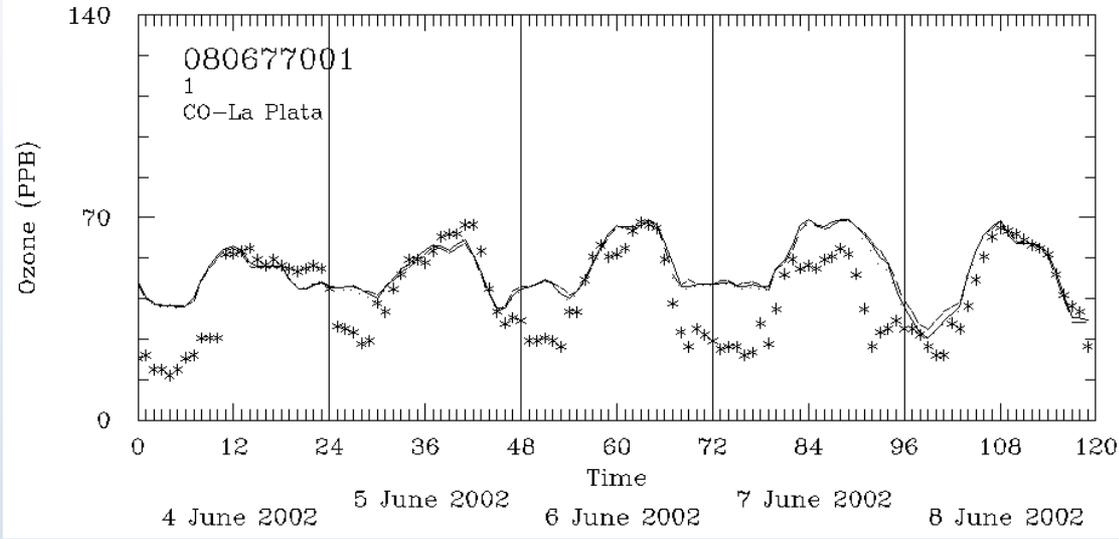


Substation:

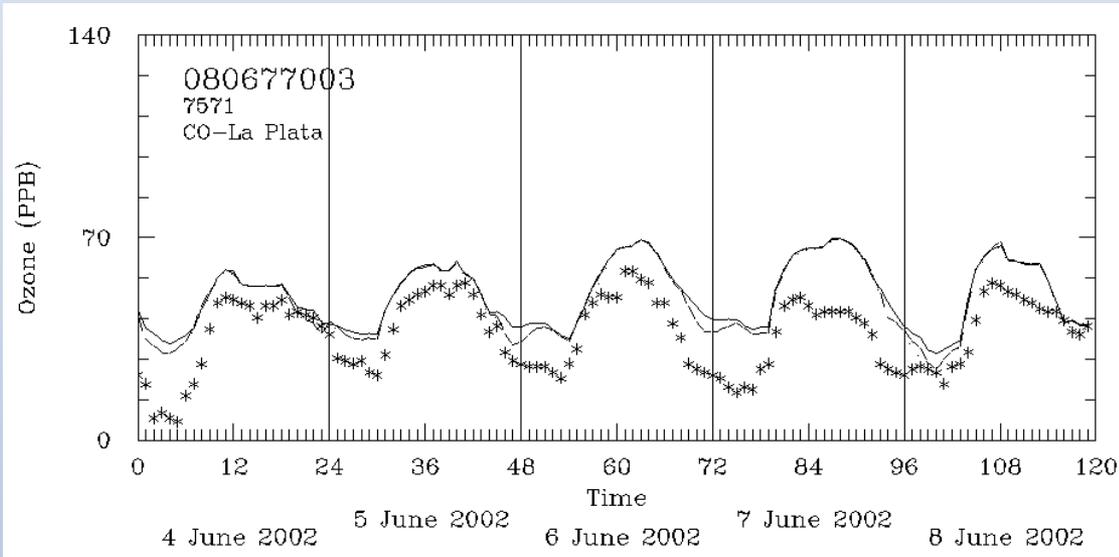


1-hr Ozone Time Series for Episode 1: 4 km Domain

Ignacio:



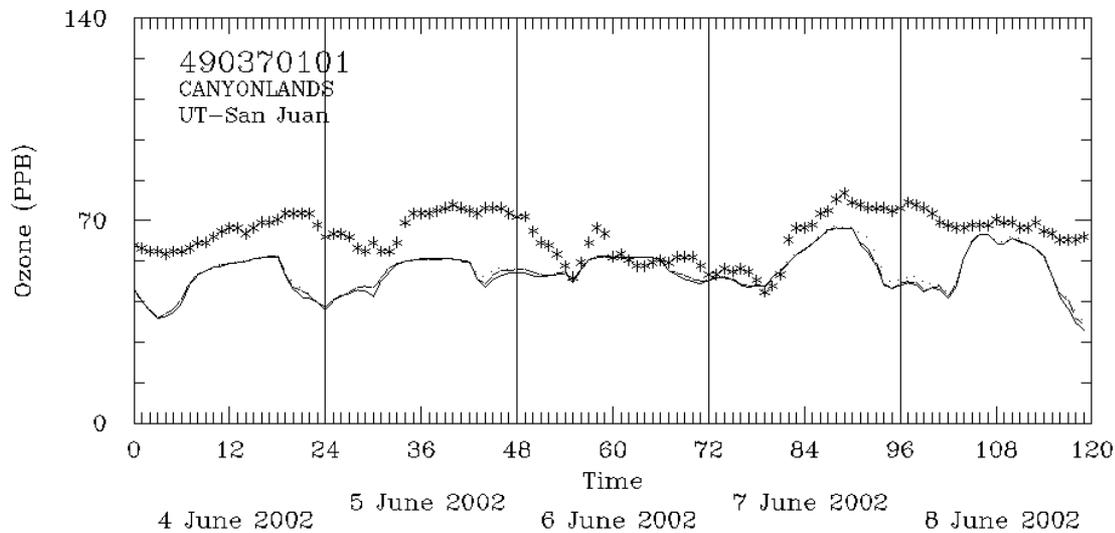
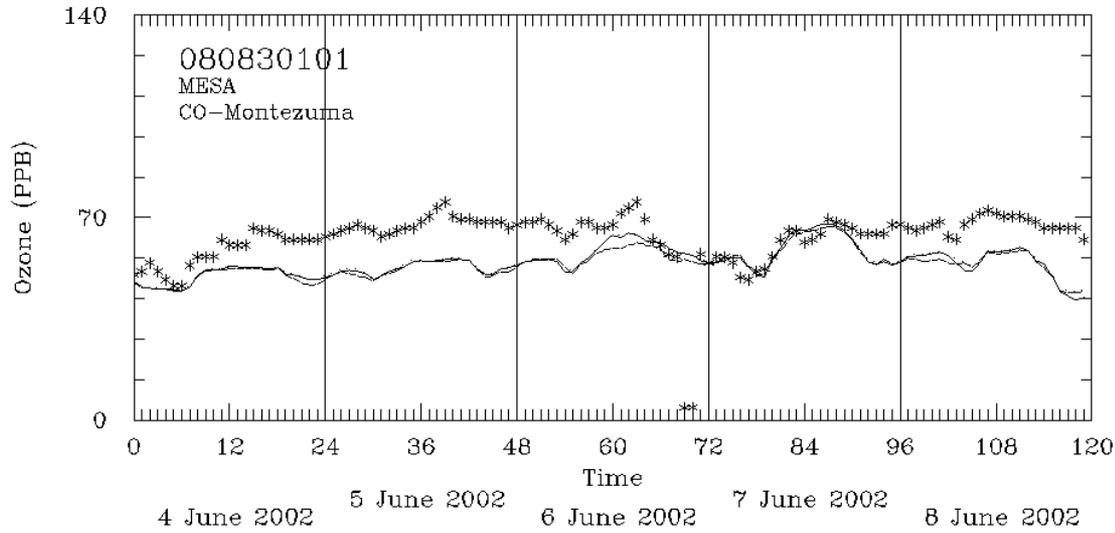
Bondad:



1-hr Ozone Time Series for Episode 1: 4 km Domain

Mesa Verde:

Canyonlands:



CAMx 1-hr Ozone MPE

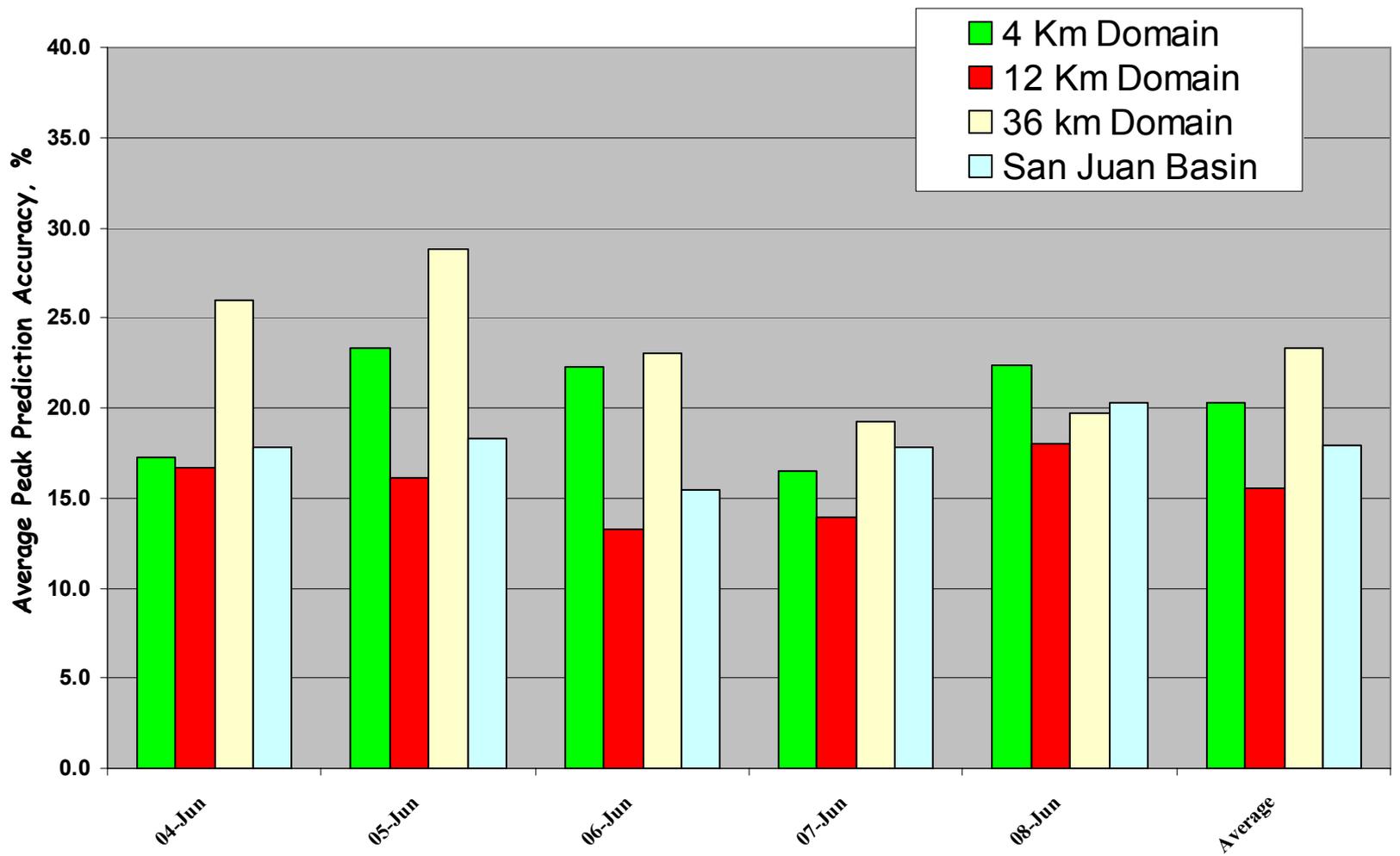
Table 1a. CAMx 1-hr Ozone MPE for San Juan EAC Episodes 1-4: FC Analysis Domain

		Four Corners Analysis Region											
Date	Day	ATS	FB	FE	AU	A-MEAN	N. Bias	Bias	N. Error	Error	Var	Max. O	Max. P
04-Jun	155	-30.9	-8.5	12.6	10.1	17.9	-12.4	-7.4	18.0	10.0	97.7	70.0	77.1
05-Jun	156	-29.2	-13.1	14.8	-15.6	18.3	-18.9	-12.1	24.2	14.7	153.7	87.0	73.4
06-Jun	157	-38.6	-5.2	9.9	-9.8	15.5	-6.0	-4.5	17.1	10.2	157.0	78.0	70.3
07-Jun	158	-18.0	5.5	13.8	6.2	17.8	1.8	-0.9	22.2	12.3	233.7	78.0	82.9
08-Jun	159	-27.7	-6.6	14.7	-1.6	20.3	-14.4	-10.7	24.2	15.4	216.5	79.0	77.7
16-Jun	167	-16.4	-5.8	5.9	-0.4	8.3	-8.9	-6.5	18.3	11.1	119.1	78.0	77.7
17-Jun	168	-34.2	-10.6	10.6	2.3	13.7	-7.6	-6.0	17.5	10.8	123.2	87.0	89.0
18-Jun	169	-23.9	-3.6	7.0	18.4	8.8	-4.8	-3.9	18.4	10.8	139.7	79.0	93.5
19-Jun	170	-21.7	-7.9	9.5	4.3	13.3	-8.9	-7.1	19.7	12.8	181.6	80.0	83.4
30-Jun	181	5.8	4.2	4.2	17.4	10.3	-0.9	-1.1	17.6	9.2	136.4	66.0	77.5
01-Jul	182	-21.9	-5.7	5.7	6.9	11.3	-22.2	-12.3	26.2	14.1	154.4	67.0	71.6
02-Jul	183	-34.1	-9.4	9.5	-18.6	14.9	-26.7	-16.7	28.3	17.5	192.5	91.0	74.1
16-Jul	197	-35.9	-3.8	9.5	-3.4	20.6	-13.6	-8.3	23.2	12.8	180.8	76.0	73.4
17-Jul	198	-31.0	-5.7	8.2	-11.6	16.9	-17.9	-10.7	23.8	13.6	174.2	86.0	76.0
18-Jul	199	-23.8	-4.1	5.6	-7.4	11.6	-17.4	-10.5	23.4	13.5	199.5	84.0	77.8
Average		-25.4	-5.3	9.4	-0.2	14.6	-11.9	-7.9	21.5	12.6	164.0	79.1	78.4

Salmon shaded boxes indicated those few instances where the 1-hr ozone normalized bias statistic falls outside the EPA suggested performance range ($\pm 15\%$). Green boxes identify days for which EPA 8-hr performance goals are met or exceeded for all bias, error, and accuracy measures.

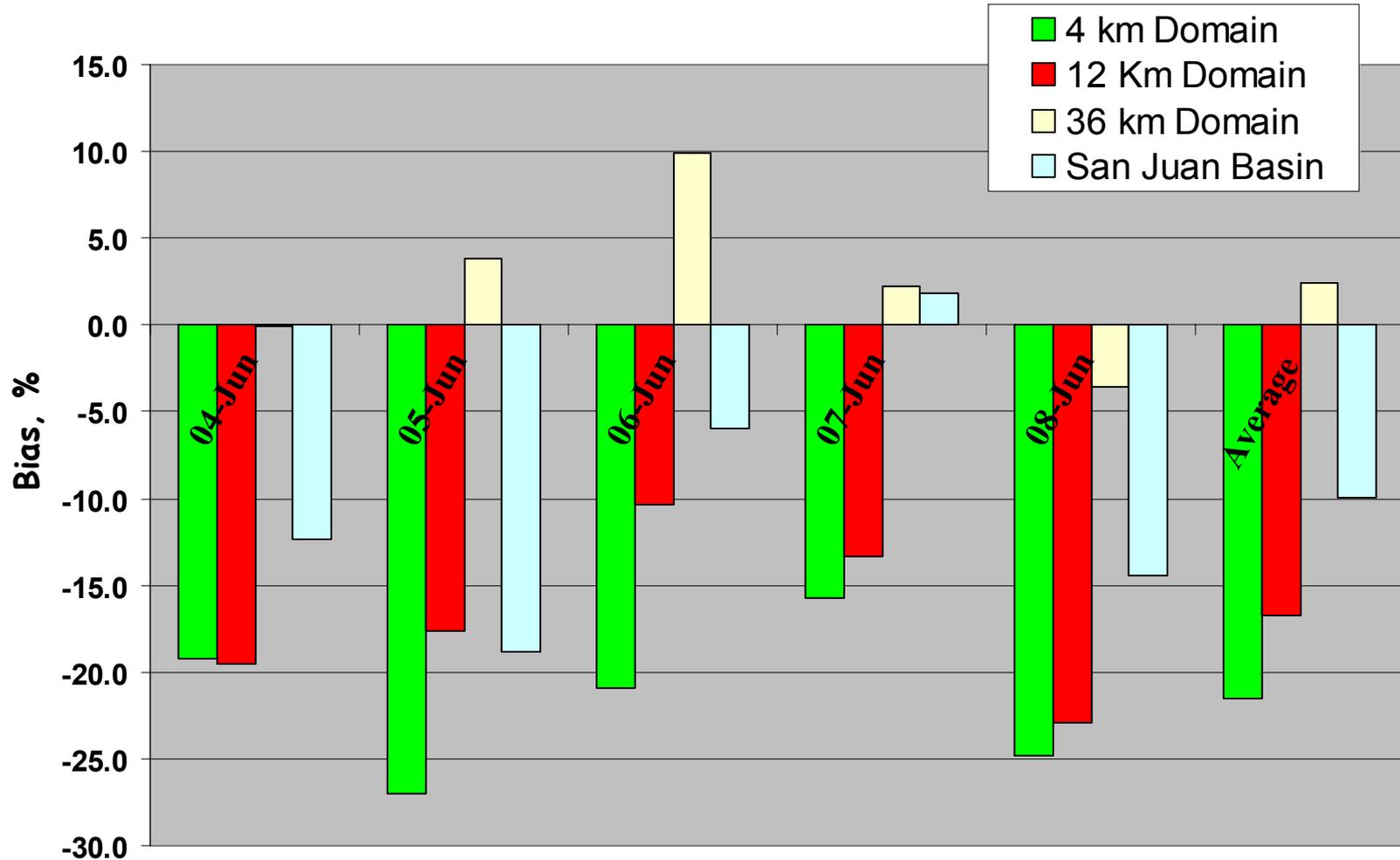
Accuracy of Peak 1-hr Ozone (All Stations)

Average Peak Accuracy over All Stations, (%).



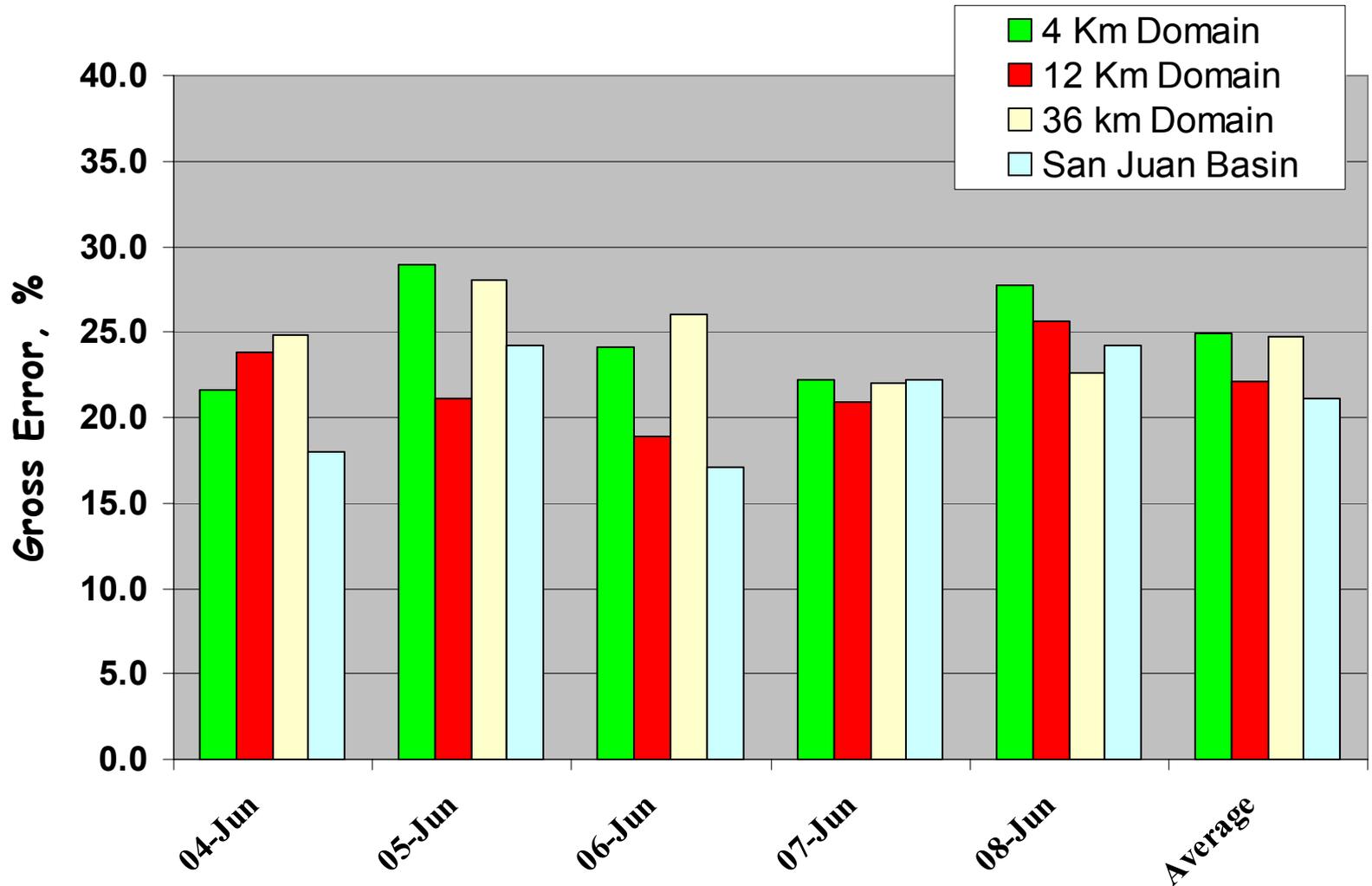
Mean Normalized Bias in 1-hr Ozone

Mean Normalized Bias in 1-Hr Ozone, (%)



Normalized Gross Error in 1-hr Ozone

Mean Normalized Gross Error in 1-Hr Ozone, (%)



EPA 1-Hour Ozone Guidance Performance Goals (EPA, 1991)

Performance Metric

Performance Goal

Accuracy of peak unpaired (time and space) 1-hr daily maxima ozone concentration	$\leq \pm 15-20\%$
Mean normalized bias in 1-hr ozone concentrations averaged over the day	$\leq \pm 5-15\%$
Mean Normalized Gross Error in 1-hr ozone concentrations averaged over the day	$< 30-35\%$

Skill of CAMx 1-Hour Ozone Modeling Relative to EPA Goals

Performance Metric

Model Skill

Accuracy of peak unpaired (time and space) 1-hr daily maxima ozone concentration	Goal met on all 15 days
Mean normalized bias in 1-hr ozone concentrations averaged over the day	Goal met on 10 of 15 days; narrowly misses on 3 other days
Mean Normalized Gross Error in 1-hr ozone concentrations averaged over the day	Goal met on all 15 days

1-hr Ozone Performance Findings

- **Comparison of CAMx base case with EPA 1-hr ozone Goals on a day-by-day basis in Four Corners area shows:**
 - ▶ **For Unpaired Accuracy of Peak Prediction [\pm 15-20%]:**
 - **All 15 modeling days achieve the goal, most by a wide margin**
 - ▶ **For Mean Normalized Bias [\pm 5-15%]:**
 - **5 out of 15 modeling days miss the goal, but three of these five days are on the outer cusp of the range**
 - ▶ **For Mean Normalized Gross Error [$<$ 30-35%]:**
 - **All 15 modeling days pass the test by a wide margin**

Synthesis of 1-hr Results

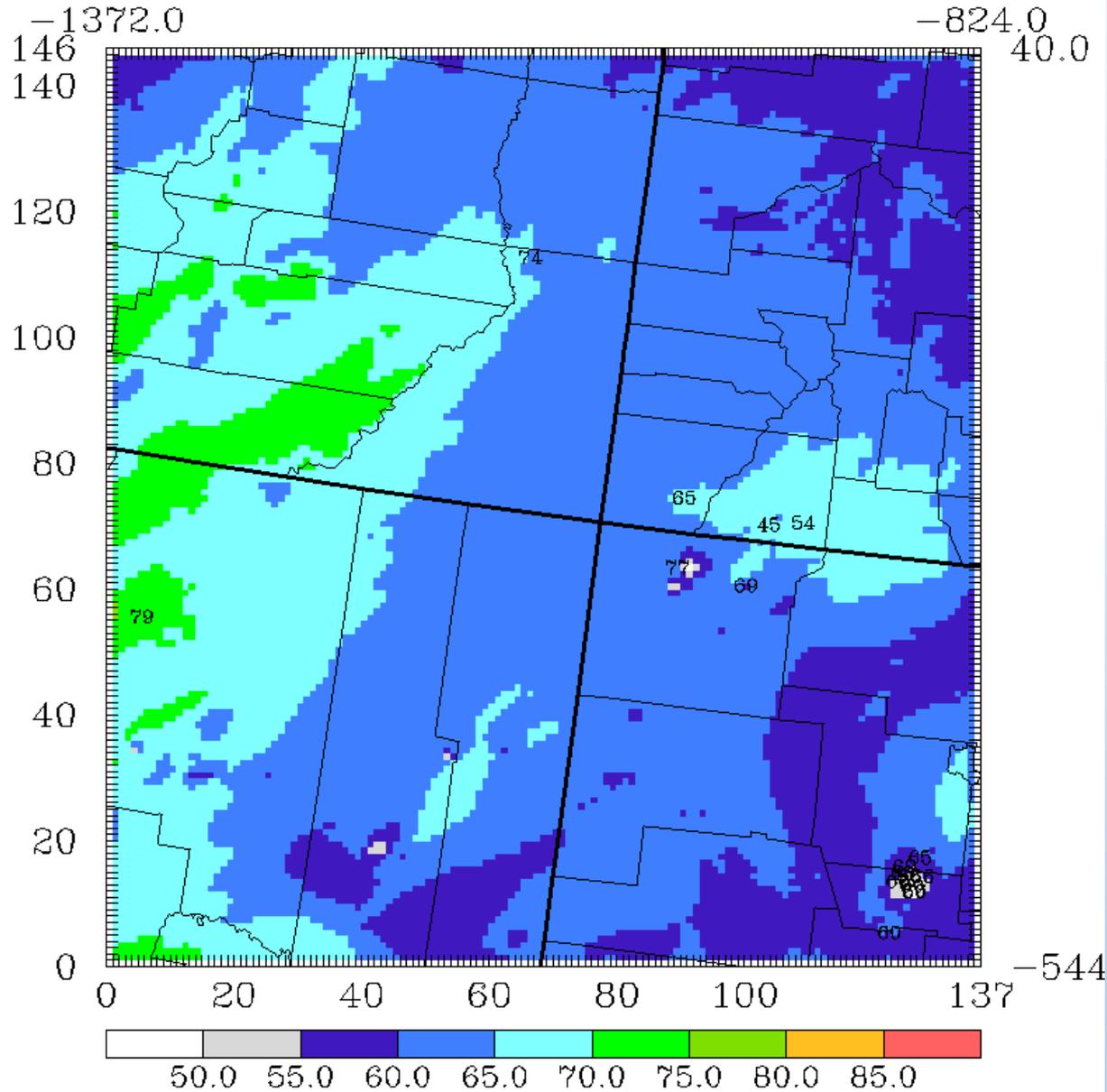
- **Across all four episodes and all three grid scales (36/12/4 km) the CAMx model produced 1-hr ozone model performance:**
 - ▶ Well within EPA performance goals in all but a few cases;
 - ▶ Better than normal in a ‘first time application’ of a photochemical modeling system to a new region; and
 - ▶ Consistent with known opportunities for data base improvements (e.g., area source emissions, on-road motor vehicle emissions) in the local area (Four Corners) and surrounding region (western U.S.).

Main concern with the four (4) San Juan base cases is the systematic tendency to underestimate ozone concentrations at some monitoring locations. This feature has been seen in other independent, corroborative modeling (CMAQ) employing similar emissions and meteorological modeling foundations.

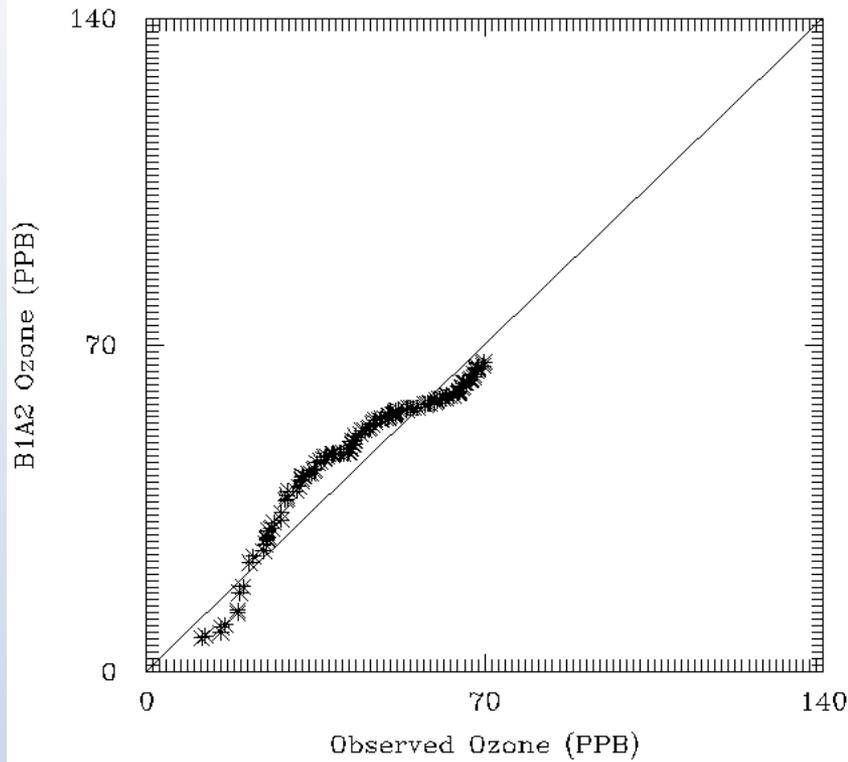
CAMx 8-hr Ozone Evaluation

- Follow EPA Draft 8-Hour Ozone Modeling Guidance Evaluation Procedures
 - ▶ Big Picture Graphical Performance
 - Spatial Maps of Predictions and Observations
 - Scatter and Q-Q Plots
 - Time Series Plots
 - ▶ Ozone Metrics
 - New 8-Hour Ozone Performance Metrics
 - Performance Goals
- Primary Evaluation Focus on Ozone
 - ▶ Very limited NO and NO_x measurements
 - ▶ No VOC or other indicator species measurements

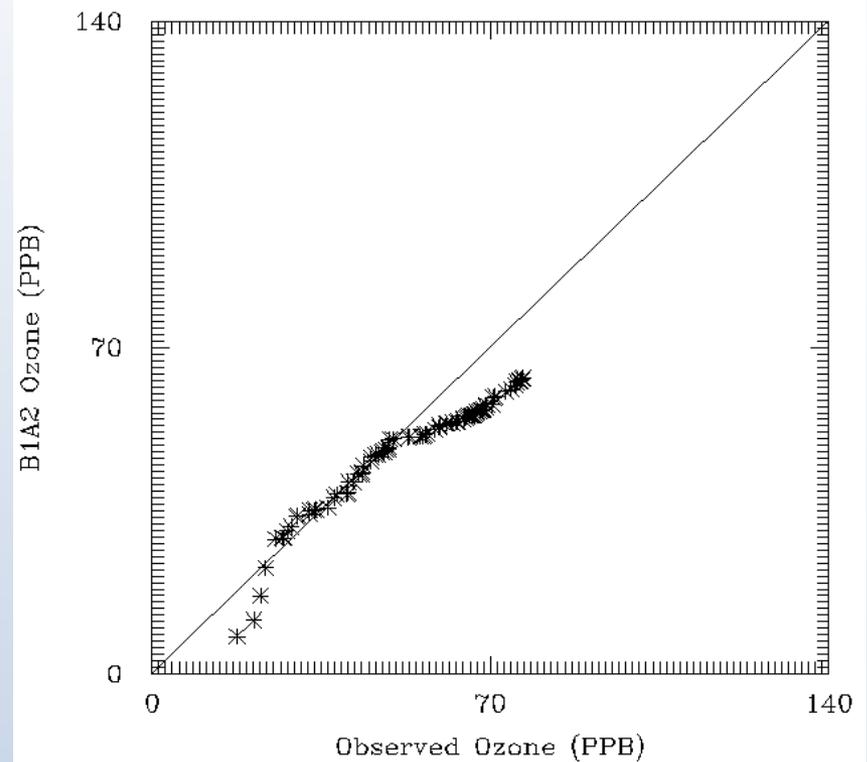
Daily Maximum 8-hr Ozone on 7 June '02



8-hr Ozone Quantile-Quantile Plots for Episode 1



6 Jun '02

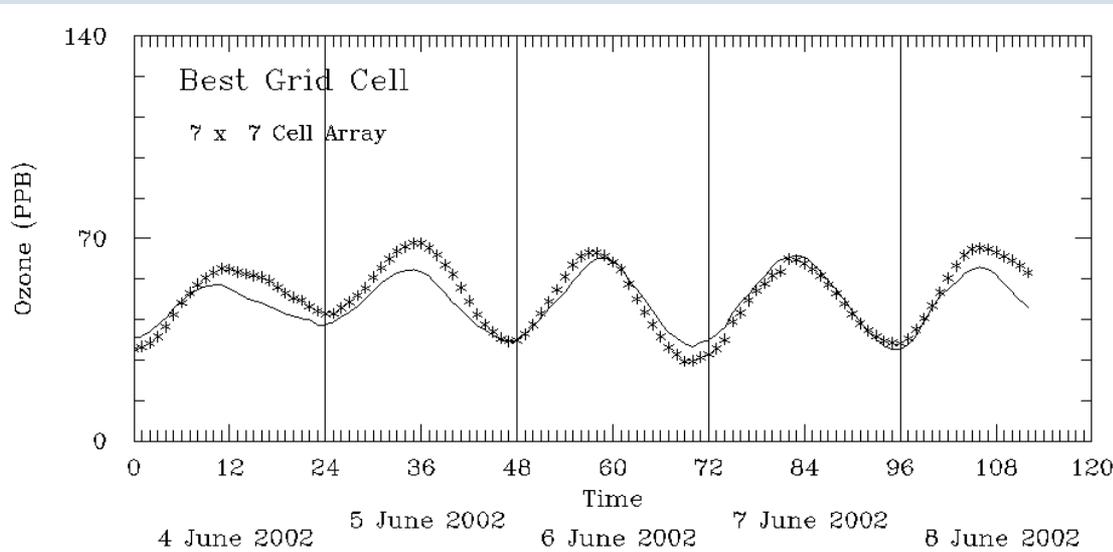
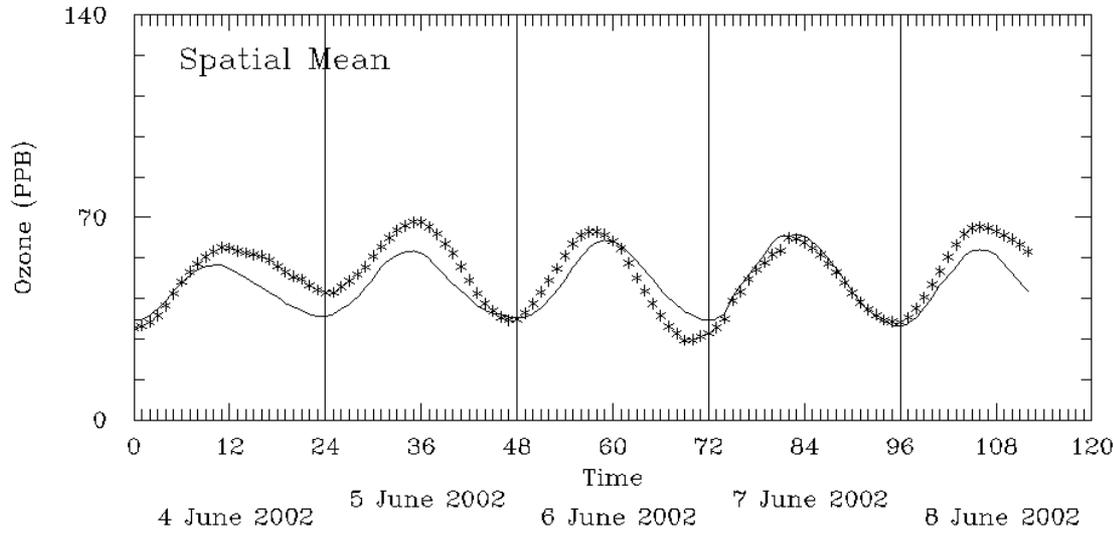


7 Jun '02

8-hr Ozone Time Series for Episode 1

Spatial Mean: (Monitor Location in 7 x 7 Cell)

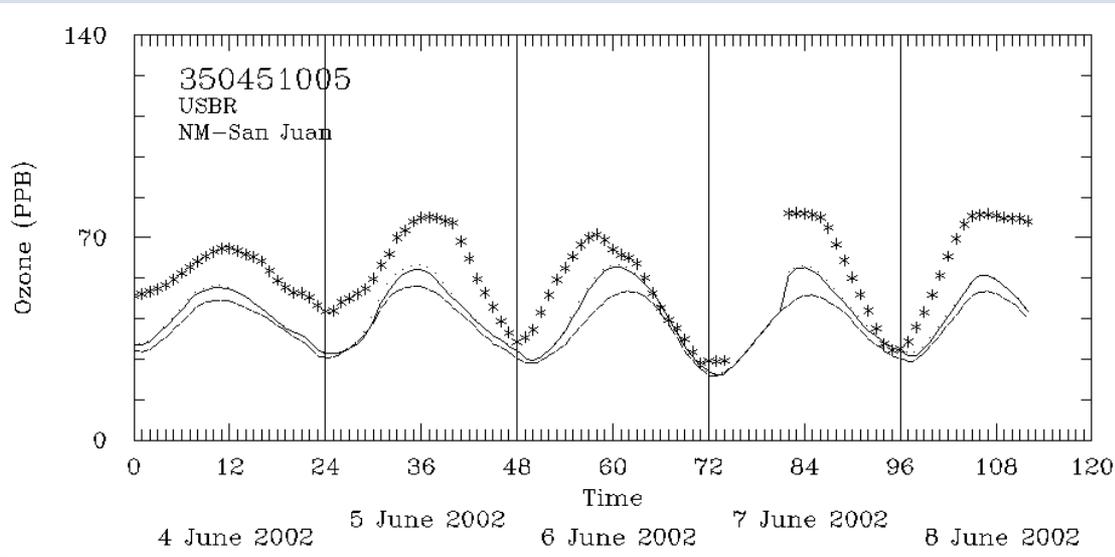
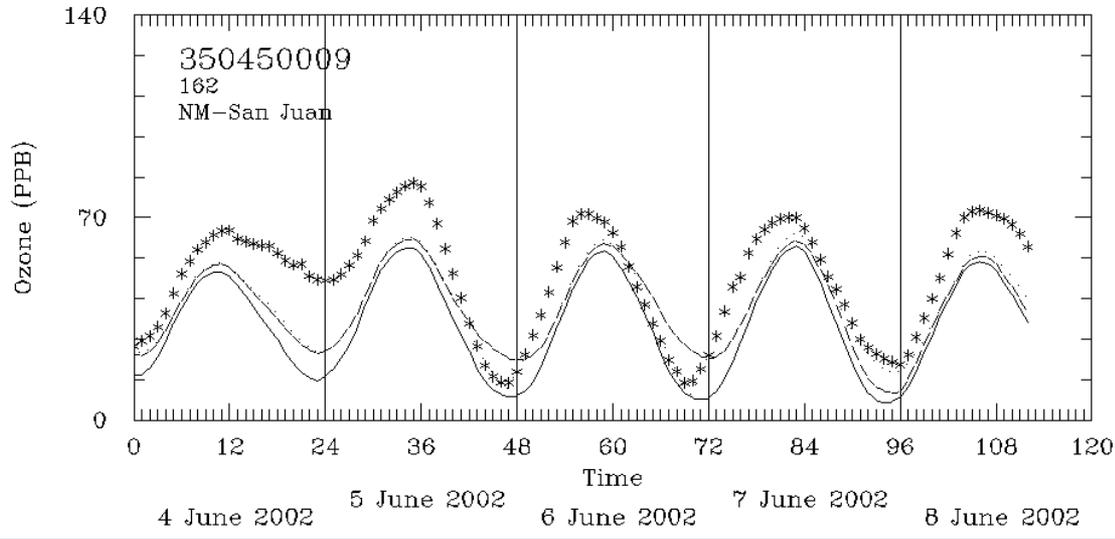
Spatial Mean: (Best Estimate in 7 x 7 Cell)



8-hr Ozone Time Series for Episode 1

Bloomfield

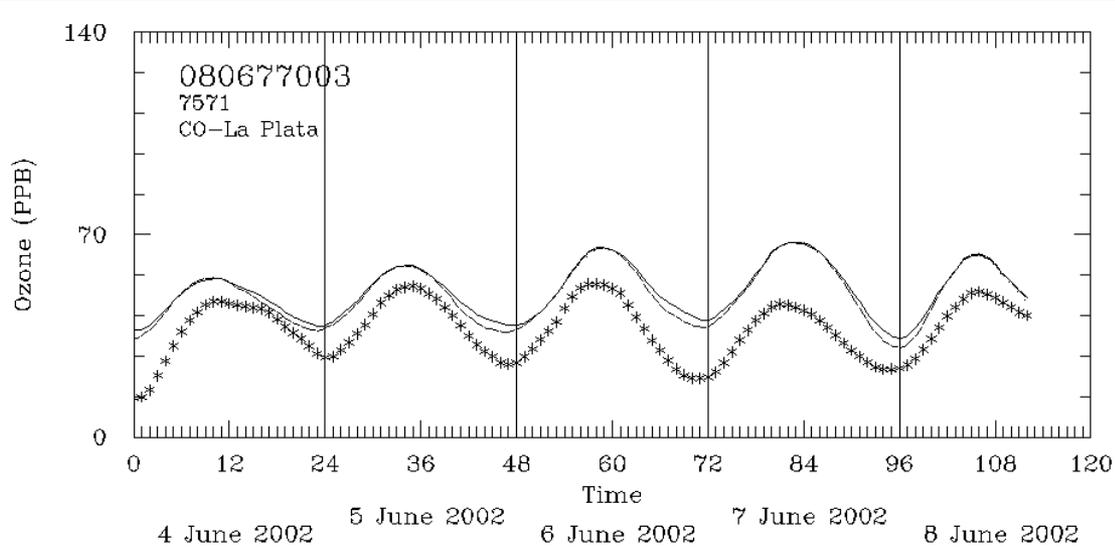
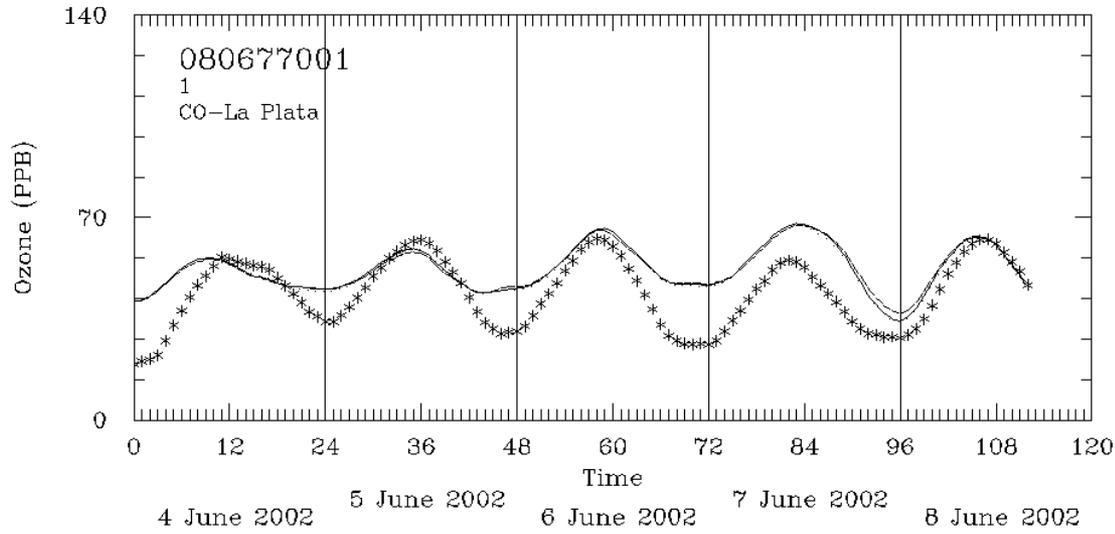
Substation



8-hr Ozone Time Series for Episode 1

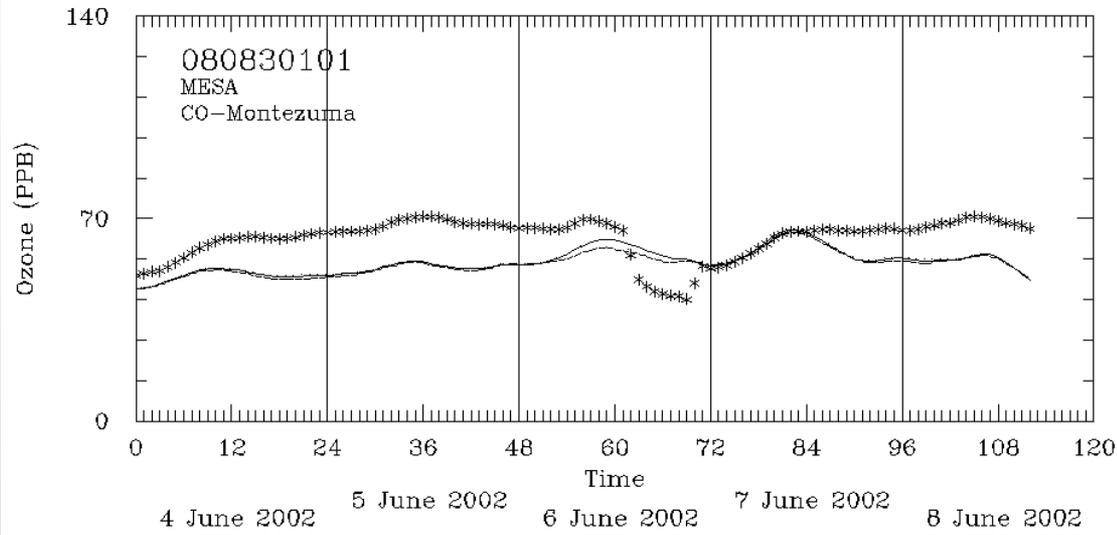
Ignacio

Bondad



8-hr Ozone Time Series for Episode 1

Mesa Verde



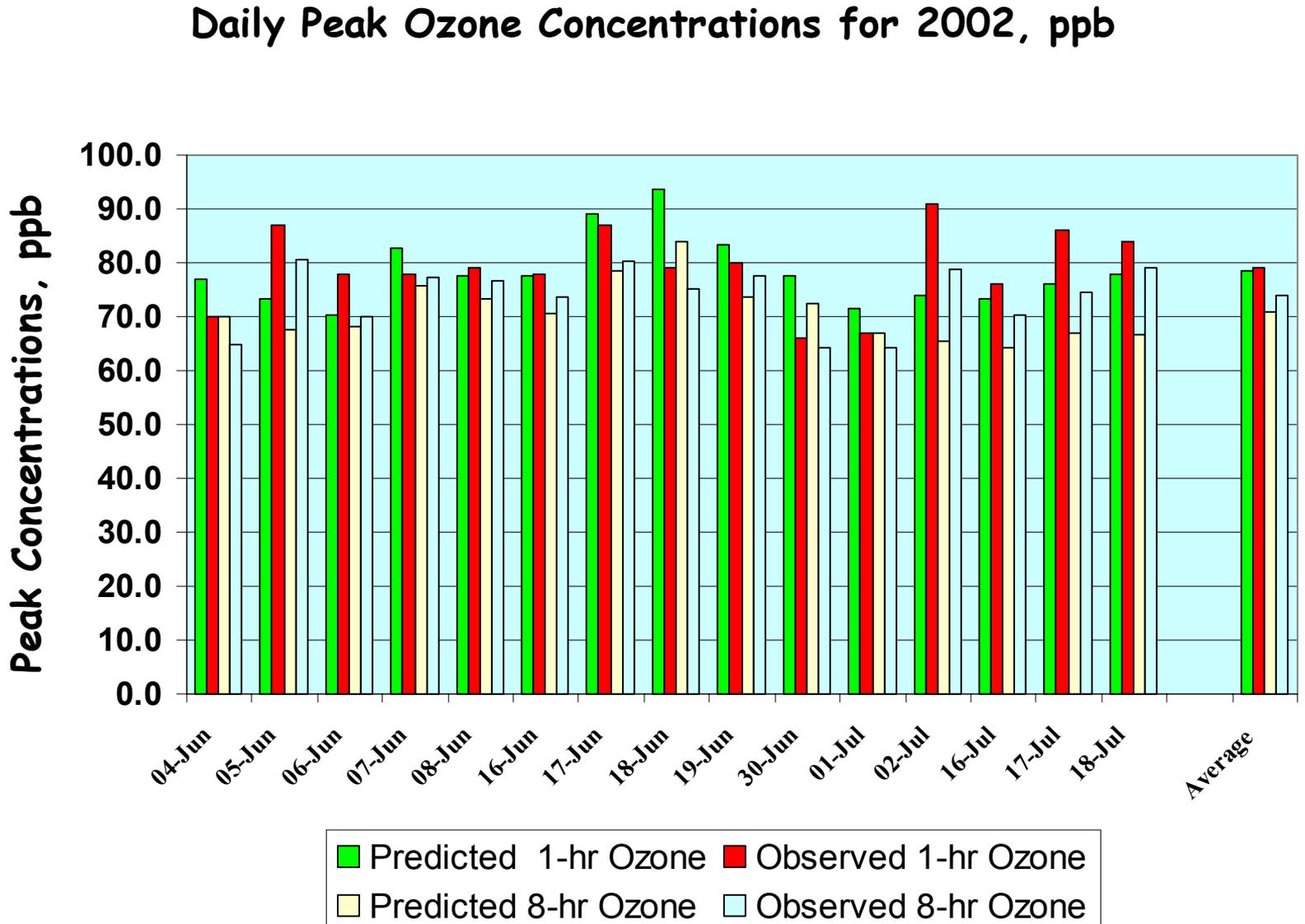
CAMx 8-hr Ozone MPE

Table 1b. CAMx 8-hr Ozone MPE for San Juan EAC Episodes 1-4: FC Analysis Domain

		Four Corners Analysis Region											
Date	Day	ATS	FB	FE	AU	A-MEAN	N. Bias	Bias	N. Error	Error	Var	Max. O	Max. P
04-Jun	155	-19.7	-7.2	12.5	7.9	16.4	-14.8	-8.6	21.1	11.4	112.6	65.0	70.1
05-Jun	156	-26.1	-11.4	14.5	-16.1	17.6	-16.0	-10.3	22.3	13.2	113.7	80.6	67.7
06-Jun	157	-21.1	-0.3	9.4	-2.2	14.8	0.7	-1.0	19.2	10.2	137.3	69.9	68.3
07-Jun	158	-23.0	5.7	16.1	-1.8	25.2	1.2	-1.1	21.8	11.6	191.6	77.1	75.8
08-Jun	159	-26.0	-7.2	16.4	-4.3	19.7	-10.6	-8.1	22.0	13.4	159.9	76.8	73.4
16-Jun	167	-19.2	-4.6	9.1	-4.4	14.0	-7.3	-5.3	18.1	10.4	94.8	73.8	70.5
17-Jun	168	-24.5	-7.2	8.7	-2.2	13.0	-7.8	-5.7	17.3	10.4	98.2	80.4	78.6
18-Jun	169	-16.2	-0.1	7.4	11.7	12.2	-1.6	-2.0	17.5	9.8	112.8	75.1	83.9
19-Jun	170	-21.3	-8.1	10.6	-5.0	16.3	-5.5	-4.8	20.7	12.3	145.4	77.5	73.6
30-Jun	181	2.0	6.6	6.8	12.9	11.3	-3.9	-2.7	17.3	8.9	132.5	64.3	72.5
01-Jul	182	-19.1	-8.5	9.5	3.9	13.9	-20.8	-11.4	24.4	13.0	92.2	64.4	66.9
02-Jul	183	-29.1	-11.3	12.2	-16.7	20.1	-19.6	-12.6	21.9	13.7	121.6	78.8	65.6
16-Jul	197	-27.3	-4.1	10.9	-8.7	19.7	-16.5	-9.4	24.0	12.8	155.8	70.3	64.1
17-Jul	198	-19.7	-4.1	9.4	-10.2	17.0	-17.6	-10.6	25.2	14.2	145.9	74.5	66.9
18-Jul	199	-29.0	-5.5	9.7	-15.8	13.6	-12.7	-7.9	20.3	11.5	151.6	79.2	66.7
Average		-21.3	-4.5	10.9	-3.4	16.3	-10.2	-6.8	20.9	11.8	131.0	73.8	71.0

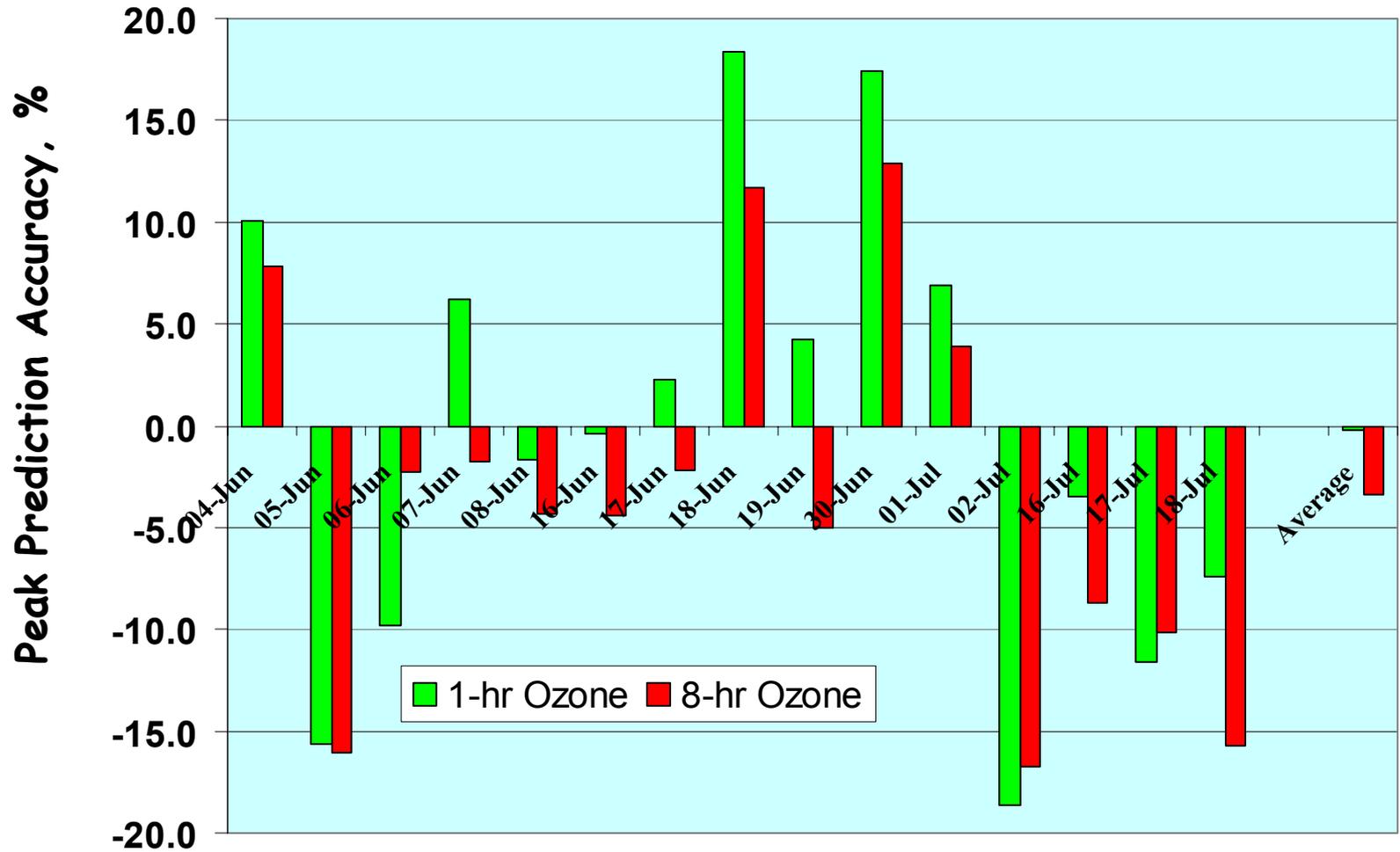
Salmon shaded boxes indicated those few instances where the 8-hr ozone normalized bias statistic falls outside the EPA suggested performance range ($\pm 15\%$). Green boxes identify days for which EPA 8-hr performance goals are met or exceeded for all bias, error, and accuracy measures.

Daily Peak Ozone: Base Case 2002

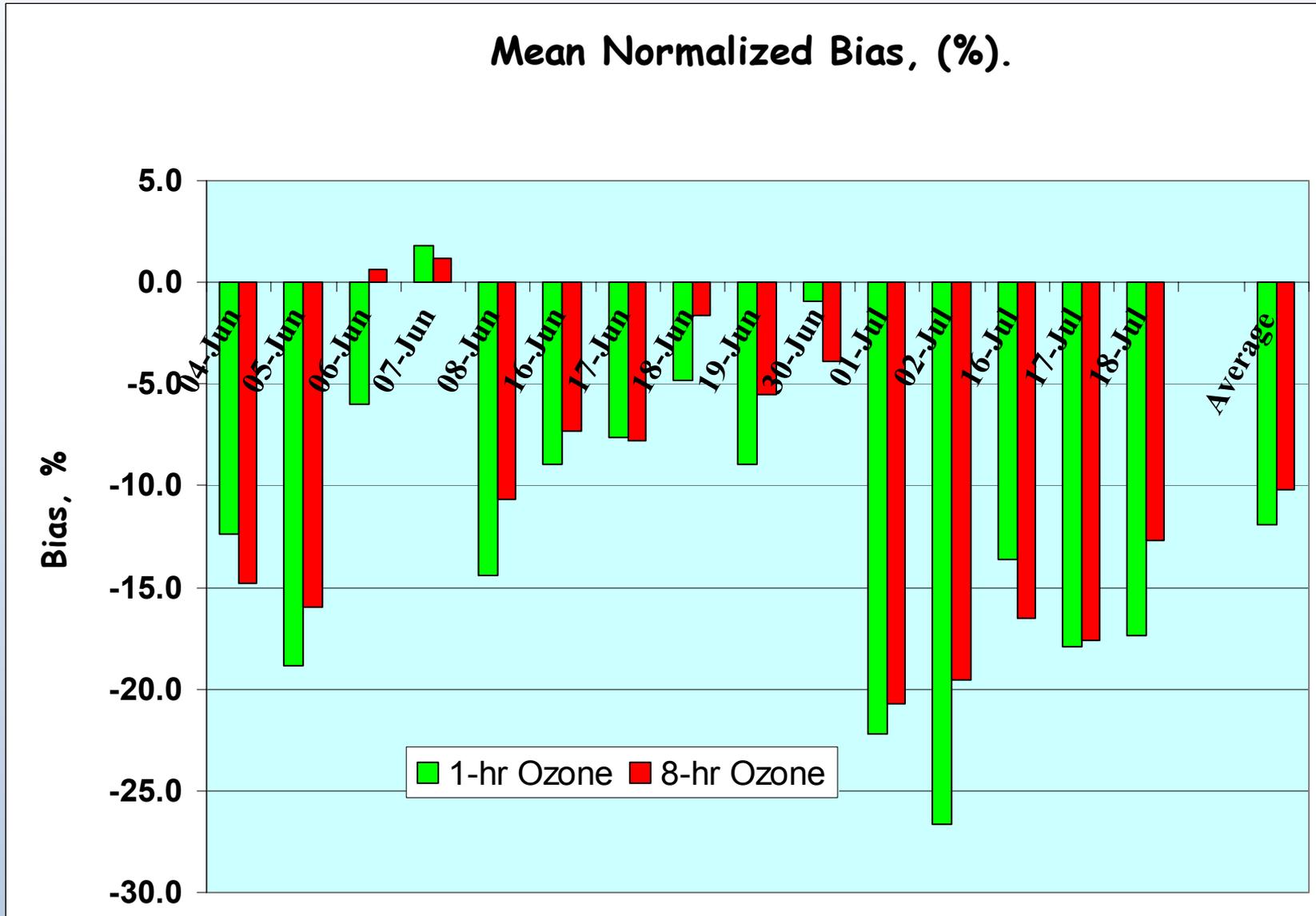


Peak Unpaired Accuracy of 8-hr Ozone

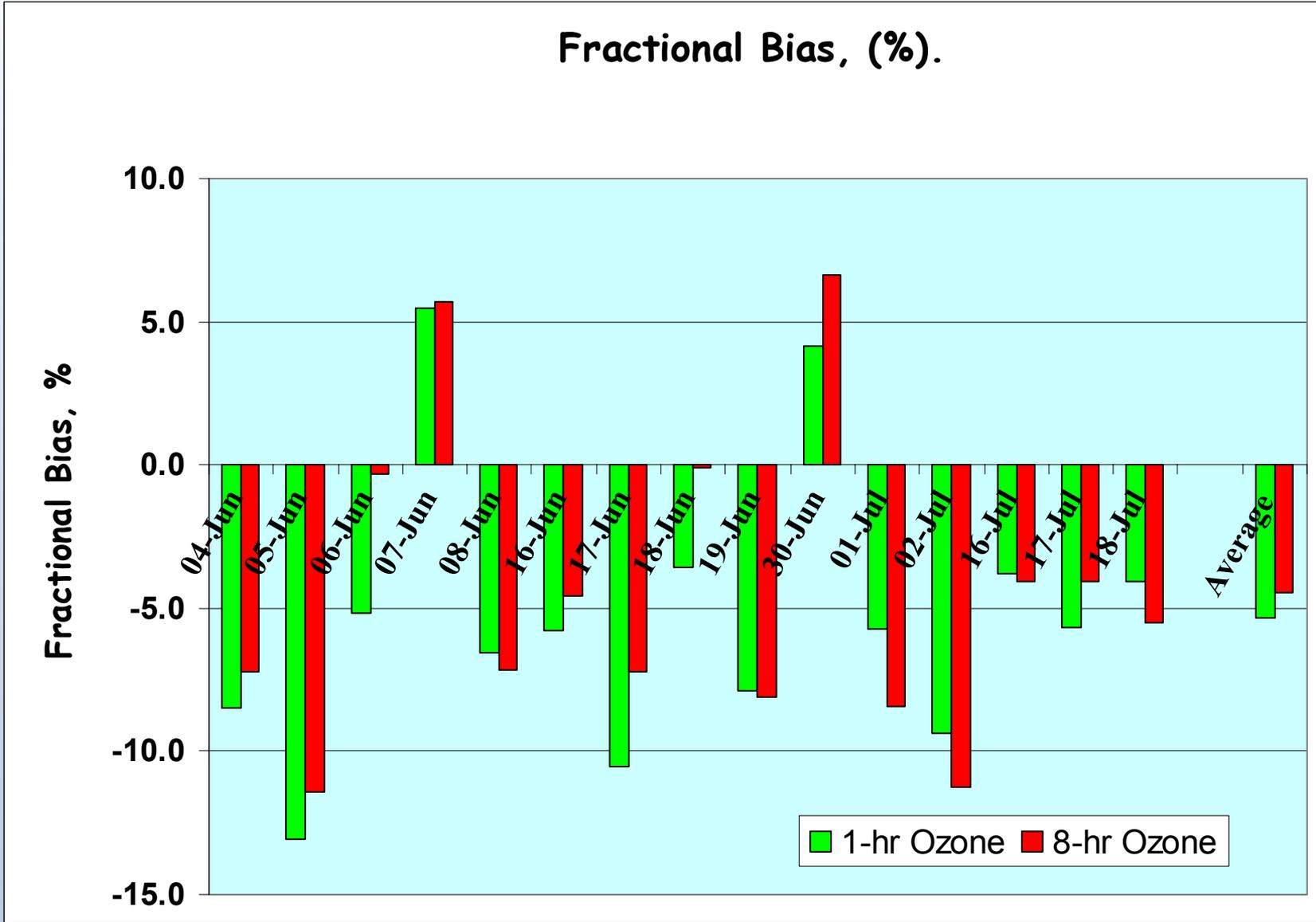
Peak Unpaired Accuracy, (%).



Mean Normalized Bias in 8-hr Ozone

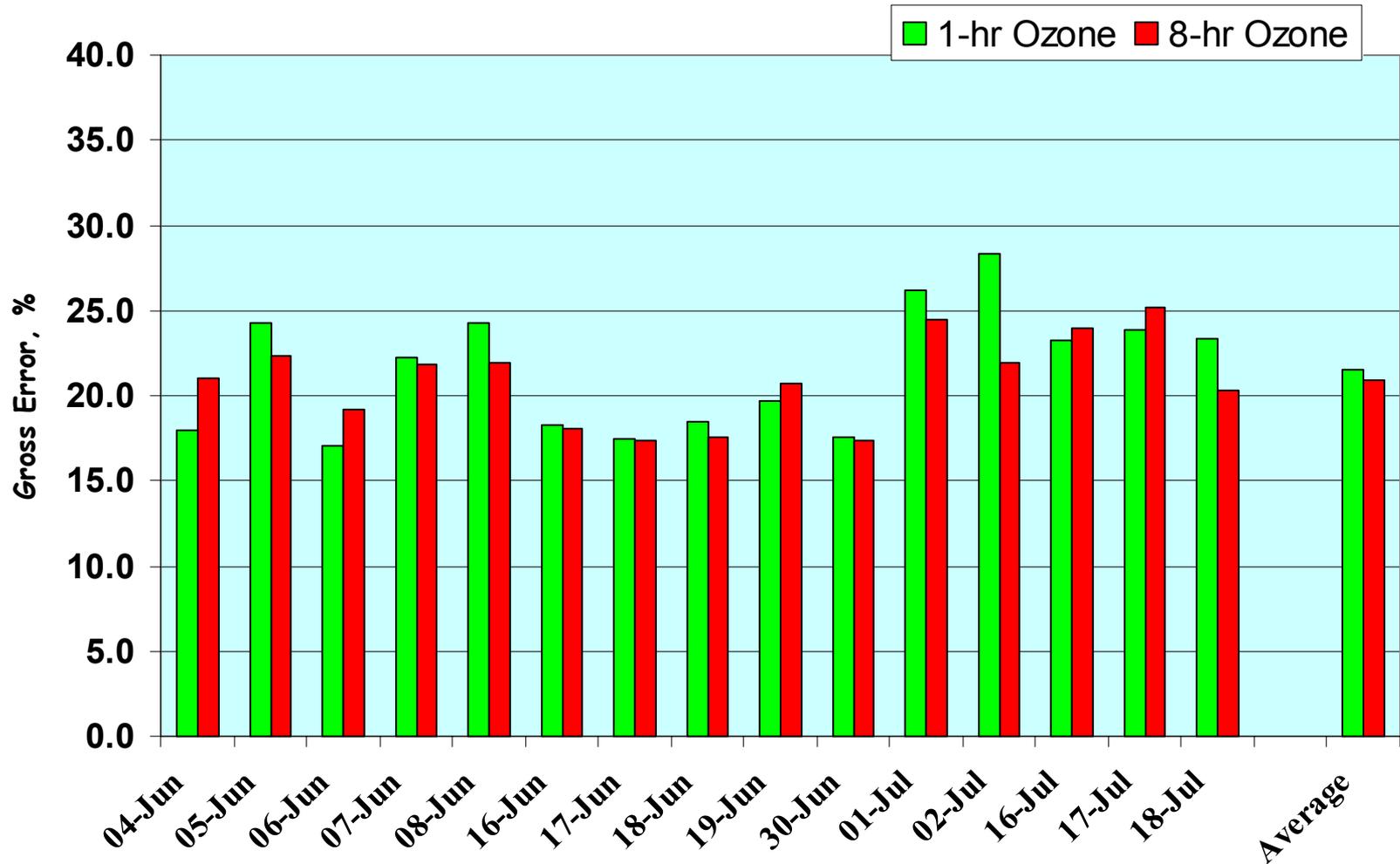


Fractional Bias in 8-hr Ozone

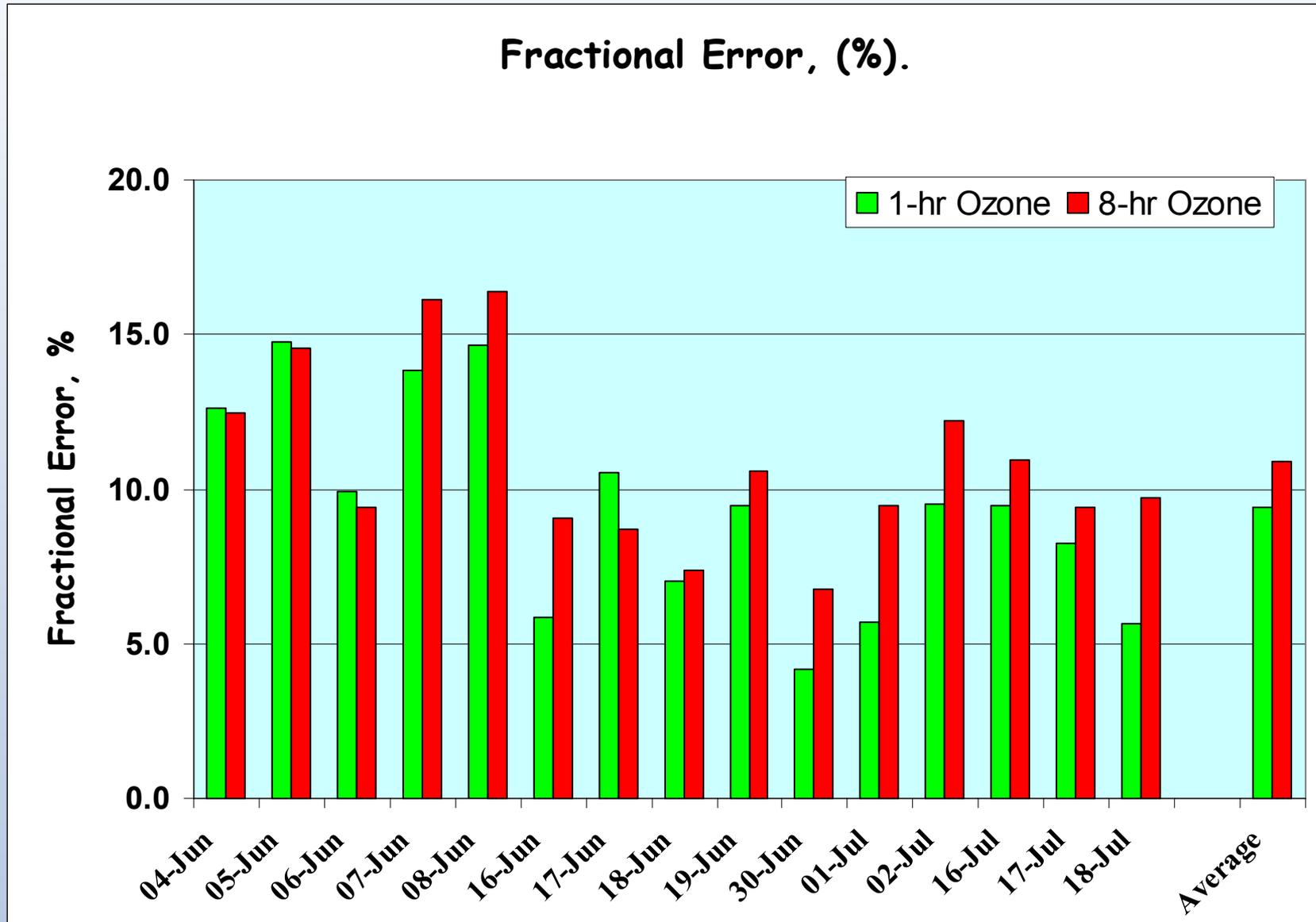


Normalized Gross Error in 8-hr Ozone

Mean Normalized Gross Error, (%).

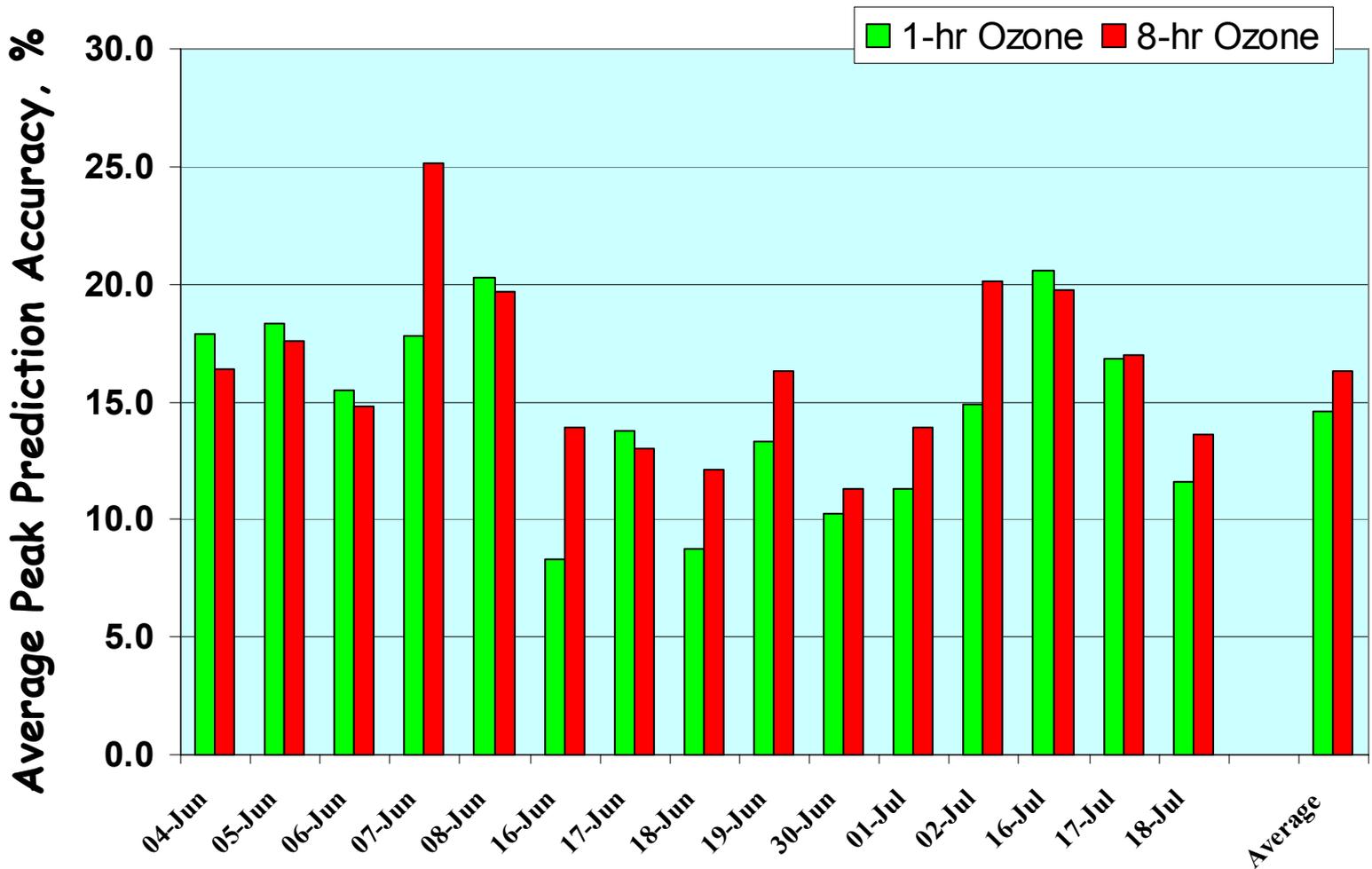


Fractional Error in 8-hr Ozone



Accuracy of Peak 8-hr Ozone (All Stations)

Average Peak Accuracy over All Stations, (%).



EPA Draft 8-Hour Ozone Guidance Performance Goals (EPA, 1999)

Performance Metric

Performance Goal

Bias in <u>daily maxima</u> 8-hr predictions and observations <u>over several days</u>	~20% at most monitors
Fractional bias in <u>daily maxima</u> 8-hr predictions and observations <u>over several days</u>	~20% at most monitors
Bias in 8-hr daily max and 1-hr daily average over all monitors	~5-15%
Gross error in 8-hr daily max and 1-hr daily average over all monitors	~30-35%
Scatter plots & Q-Q plots of 8-hr and 1-hr concentration distributions	
Correlation coefficients based on all predictions-observations, paired in time and space	Moderate to large positive correlations (i.e., small variance)

Skill of CAMx 8-Hour Ozone Modeling Relative to EPA Goals

Performance Metric

Model Skill

Bias in <u>daily maxima</u> 8-hr predictions and observations <u>over several days</u>	Bias in daily maximum 8-hr predictions over the 15 episode days is below 20% on 91% of the modeling days.
Fractional bias in <u>daily maxima</u> 8-hr predictions and observations <u>over several days</u>	Fractional bias in daily 8-hr predictions over the 15 episode days is below 20% on 83% of the modeling days.
Bias in 8-hr daily max and 1-hr daily average over all monitors	Bias for 8-hr & 1-hr predictions are -3.6% & -11.9%, meeting EPA goal
Gross error in 8-hr daily max and 1-hr daily average over all monitors	Gross errors for 8-hr & 1-hr predictions are 20.9% & 21.5%, meeting EPA goal
Scatter plots & Q-Q plots of 8-hr and 1-hr concentration distributions	Scatter and Q-Q plots do not exhibit spurious trends
Correlation coefficients based on all predictions-observations, paired in time and space	8-hr and 1-hr variance measures (131.0, 164.0) acceptably small; value of R-squared dubious, therefore not calculated

Future Year (2007) Baseline Results

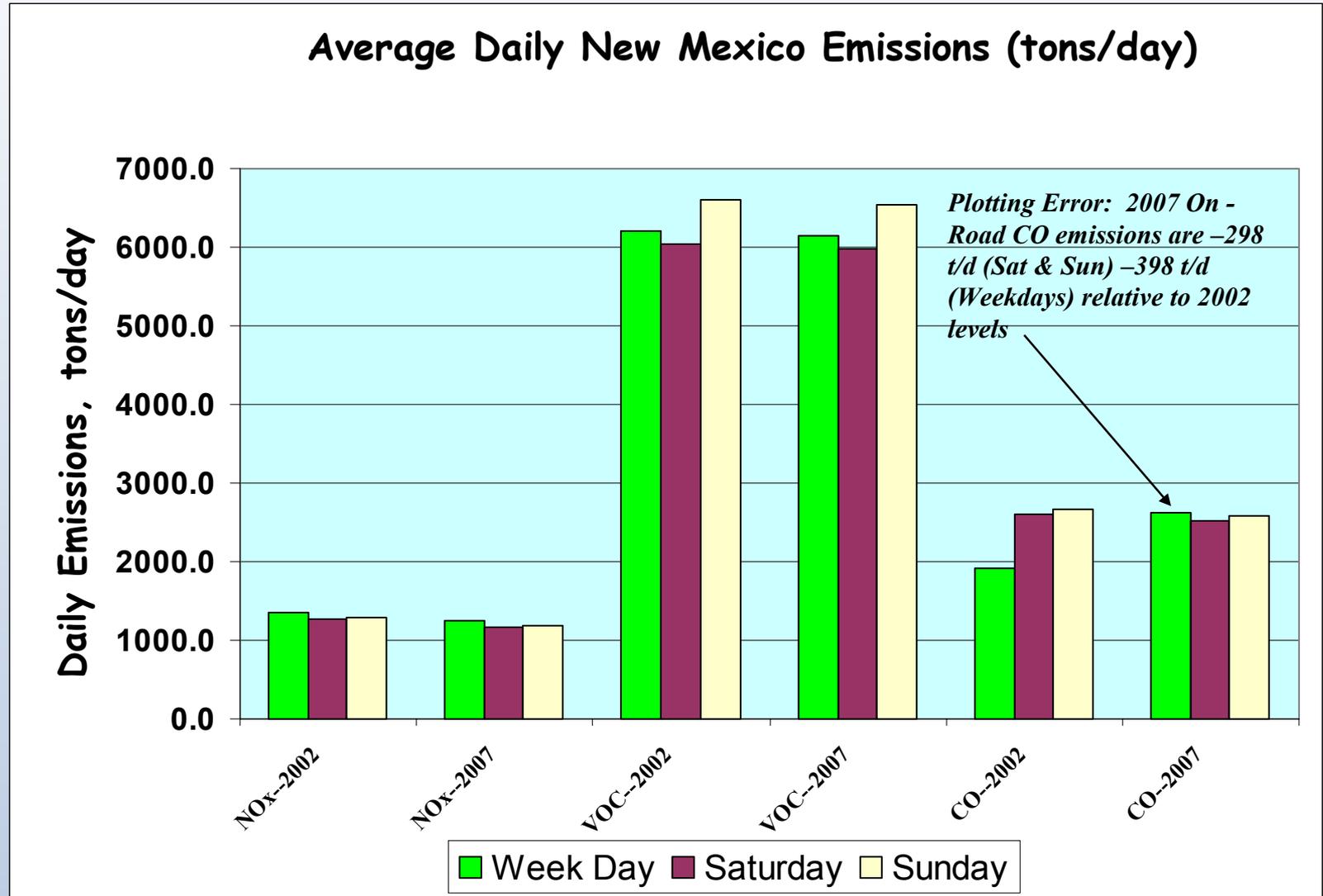


Projected 2007 Baseline Emissions

Table 1. Summary of New Mexico 2002 and 2007 Modeling Emissions (tons/day)

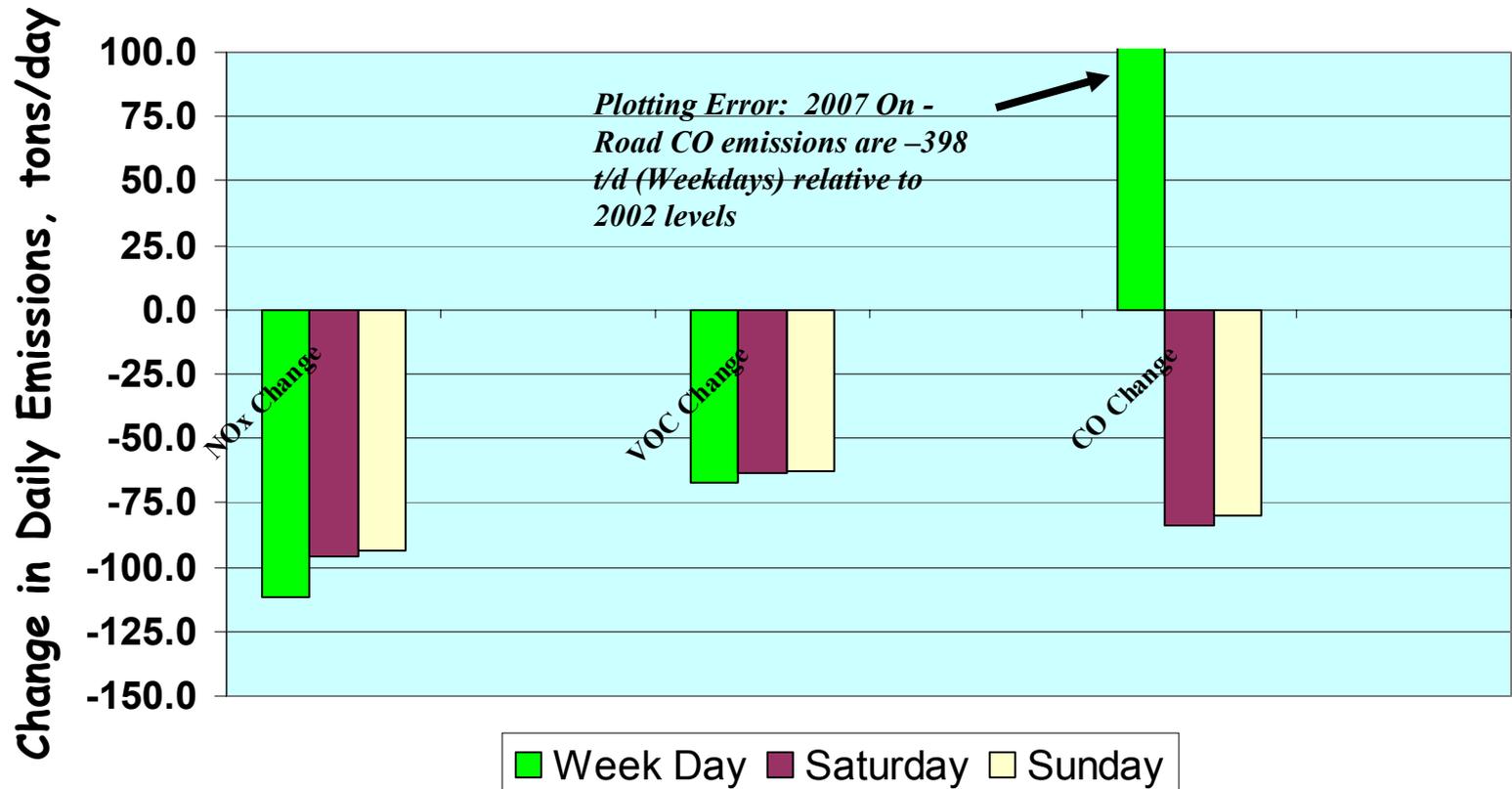
Emission	Year	Area			Off-Road			On-Road		
		Wkd	Sat	Sun	Wkd	Sat	Sun	Wkd	Sat	Sun
NOx	2002	159.5	153.1	150.0	131.4	124.4	116.3	205.7	154.3	154.3
NOx	2007	183.3	176.0	172.4	44.8	42.2	36.5	155.2	116.4	116.4
VOC	2002	309.1	309.0	309.0	45.1	73.5	72.0	139.8	104.8	104.8
VOC	2007	287.3	287.2	287.2	43.6	66.9	66.1	101.5	76.1	76.1
CO	2002	72.7	71.8	71.3	474.5	466.6	452.6	459.8	1173.3	1173.3
CO	2007	43.7	42.6	42.1	530.7	741.3	731.0	1166.3	874.7	874.7
Emission	Year	Points			Total Anthropogenic			Biogenic		
		Wkd	Sat	Sun	Wkd	Sat	Sun	Wkd	Sat	Sun
NOx	2002	418.6	418.6	418.6	915.2	850.4	839.1	437.9	412.1	443.5
NOx	2007	420.5	420.0	420.0	803.8	754.7	745.3	437.9	412.1	443.5
VOC	2002	30.8	30.8	30.8	524.7	518.1	516.6	5682.1	5524.9	6092.8
VOC	2007	24.8	24.7	24.7	457.2	455.0	454.1	5682.1	5524.9	6092.8
CO	2002	90.5	90.5	90.5	1097.5	1802.3	1787.8	825.7	799.1	885.7
CO	2007	66.9	59.7	59.7	1807.6	1718.3	1707.5	825.7	799.1	885.7
Emission	Year	Total								
		Wkd	Sat	Sun						
NOx	2002	1353.1	1262.5	1282.6						
NOx	2007	1241.7	1166.8	1188.8						
VOC	2002	6206.8	6043.0	6609.4						
VOC	2007	6139.3	5979.9	6546.9						
CO	2002	1923.2	2601.3	2673.5						
CO	2007	2633.3	2517.4	2593.2						

2002 and 2007 NM Baseline Emissions

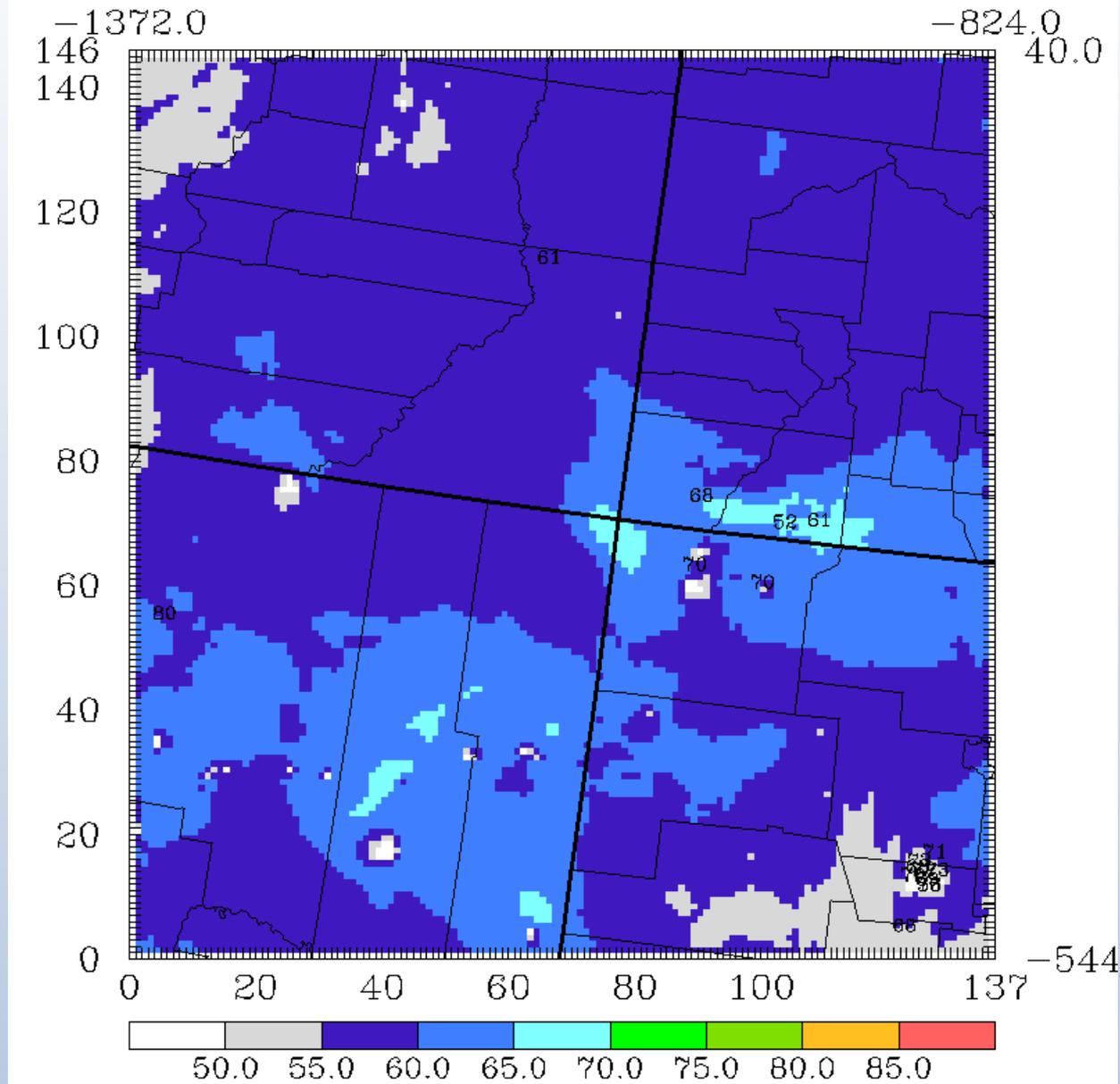


Change in NM Baseline Emissions

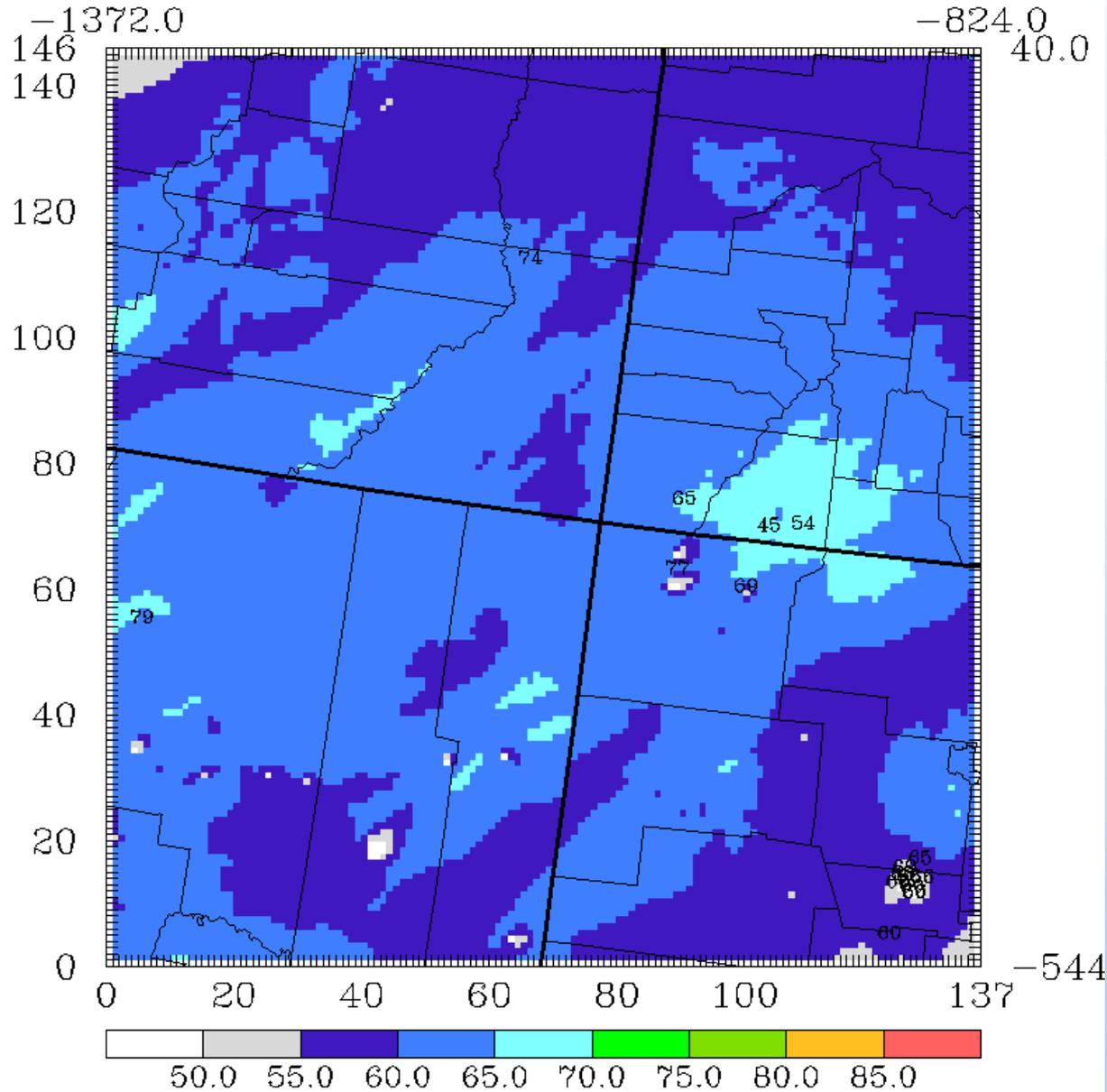
Change in Average Daily New Mexico Emissions from 2002 to 2007, (tons/day)



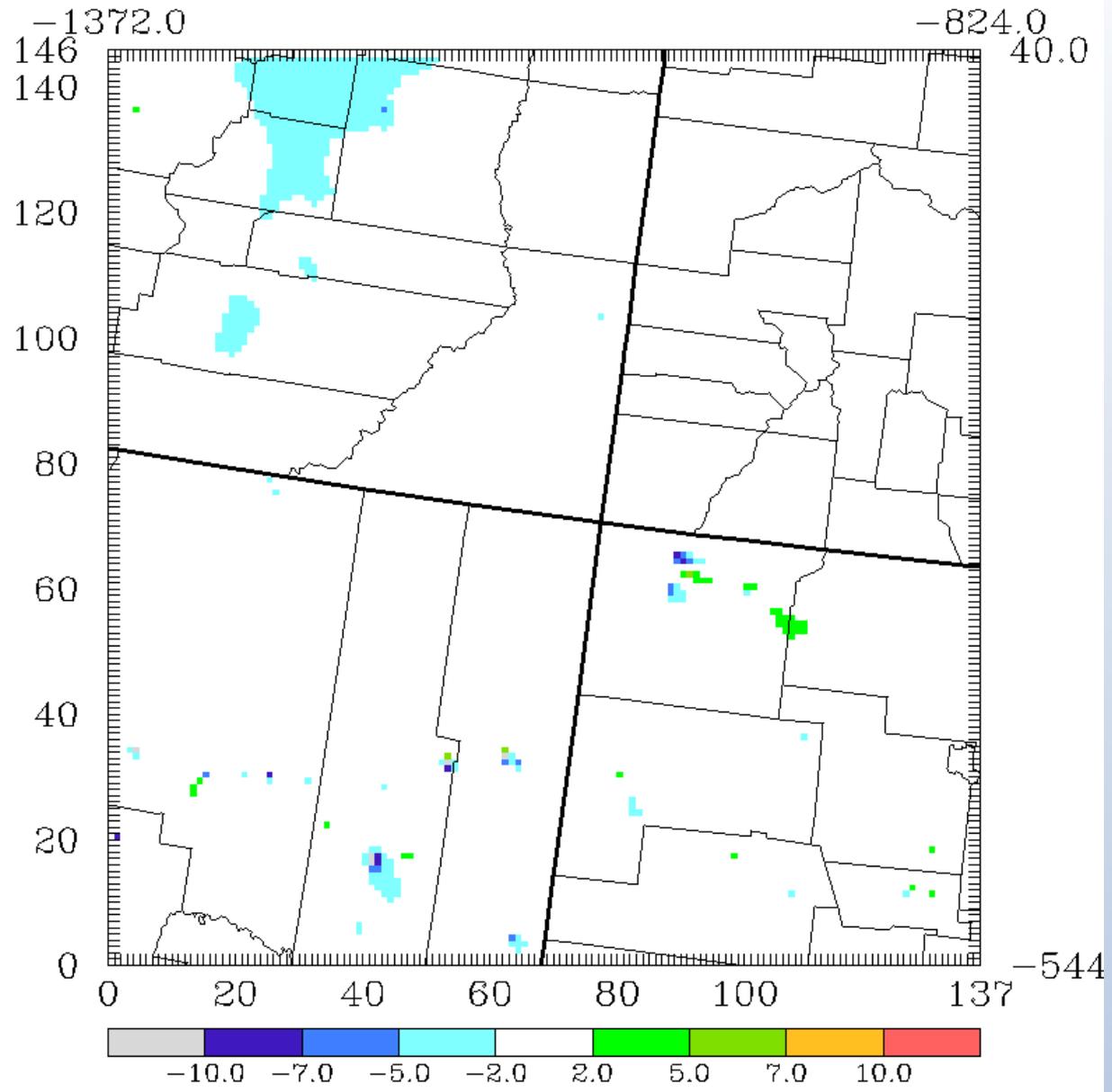
Daily Maximum 8-hr Ozone on 6 June '07



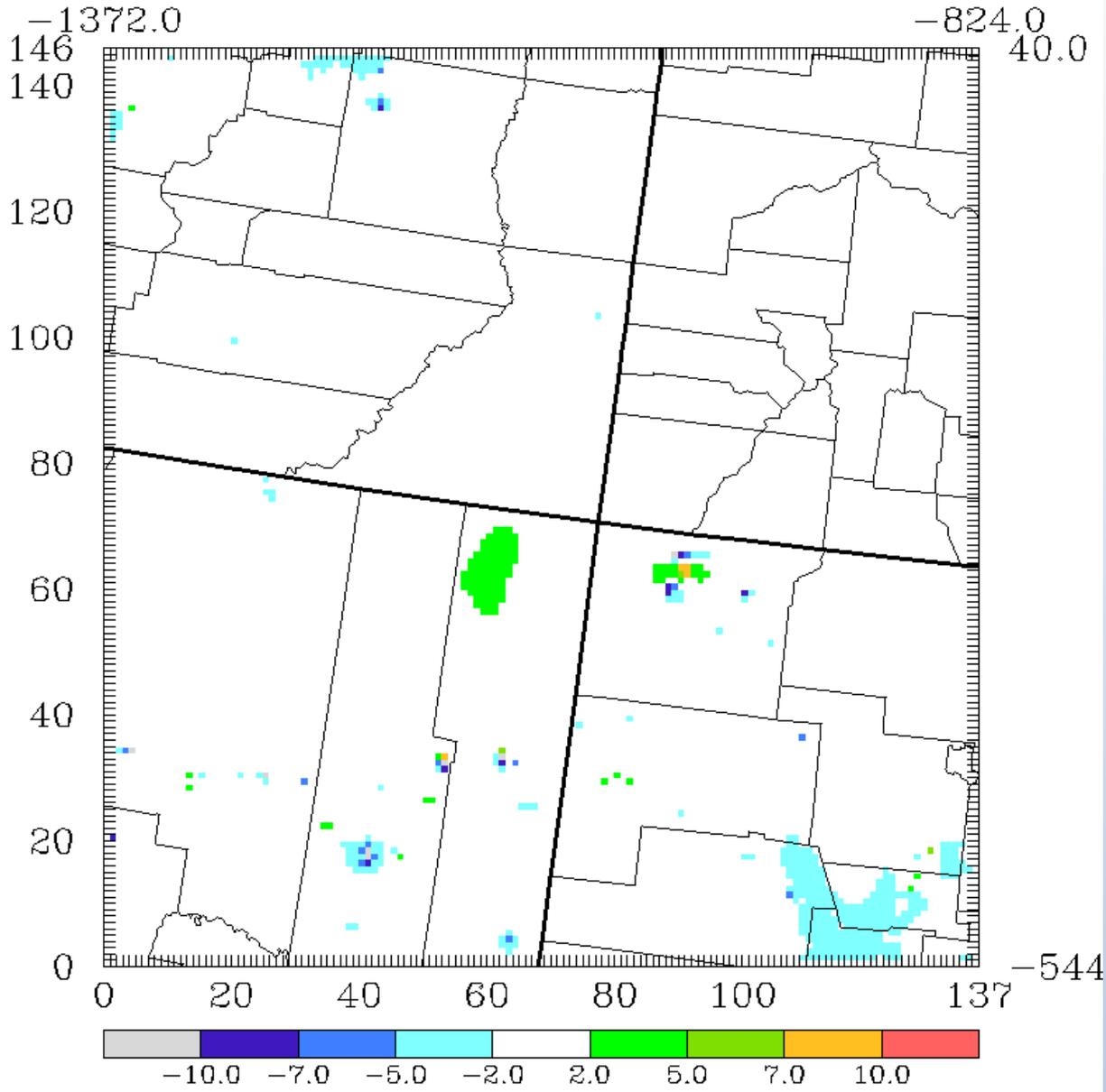
Daily Maximum 8-hr Ozone on 7 June '07



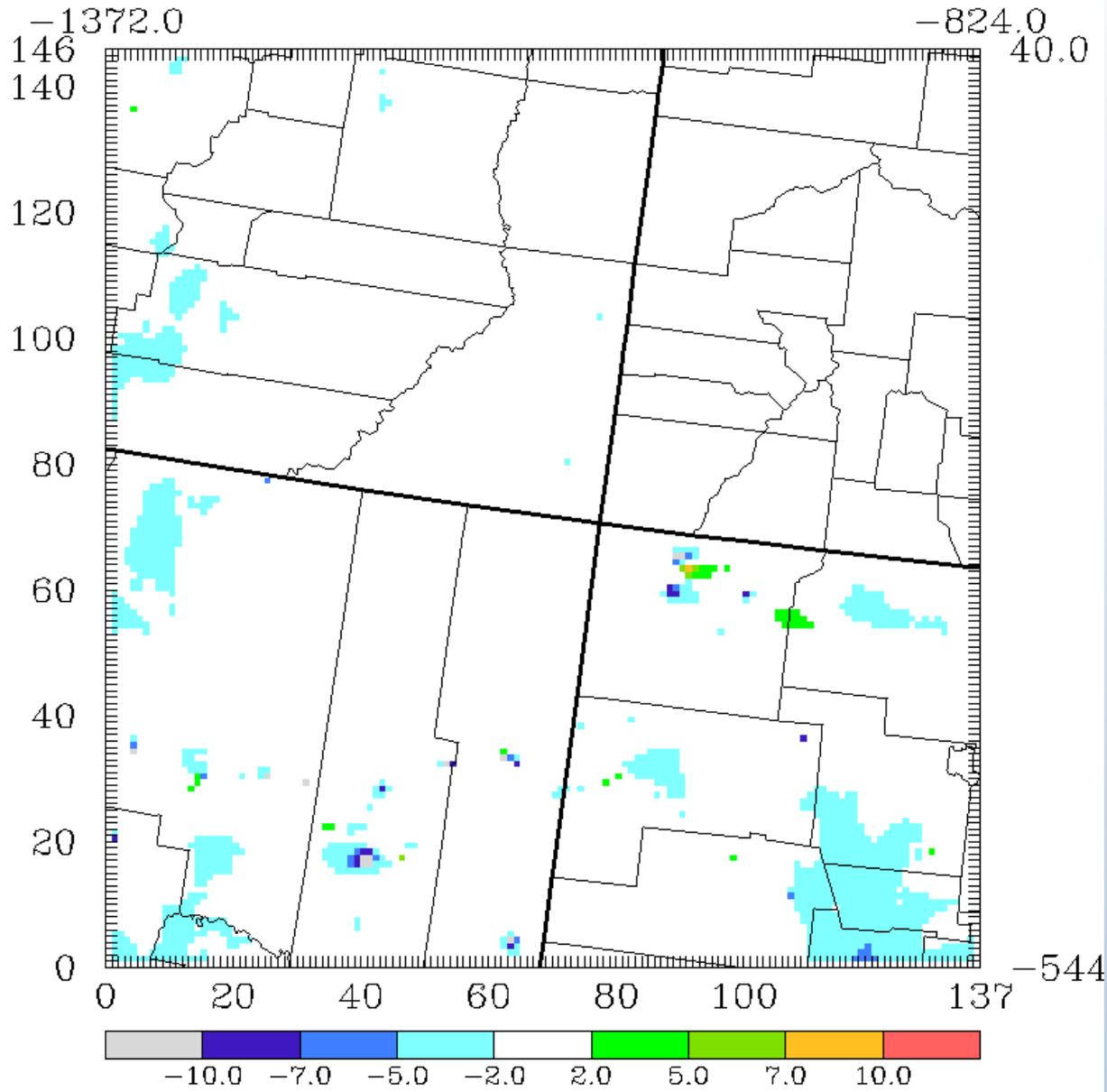
8-hr Ozone Change ('07 minus '02): 4 June



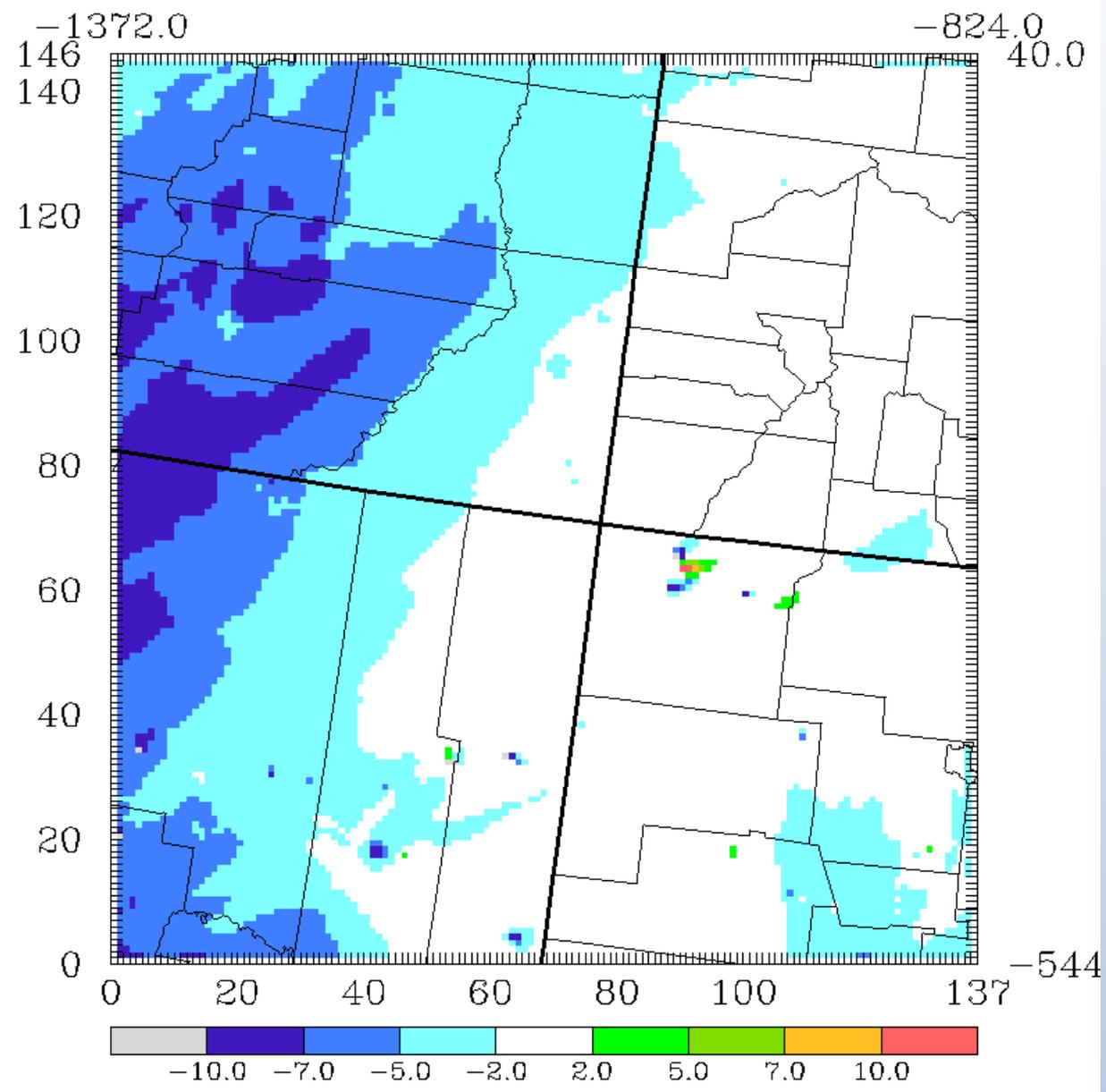
8-hr Ozone Change ('07 minus '02): 5 June



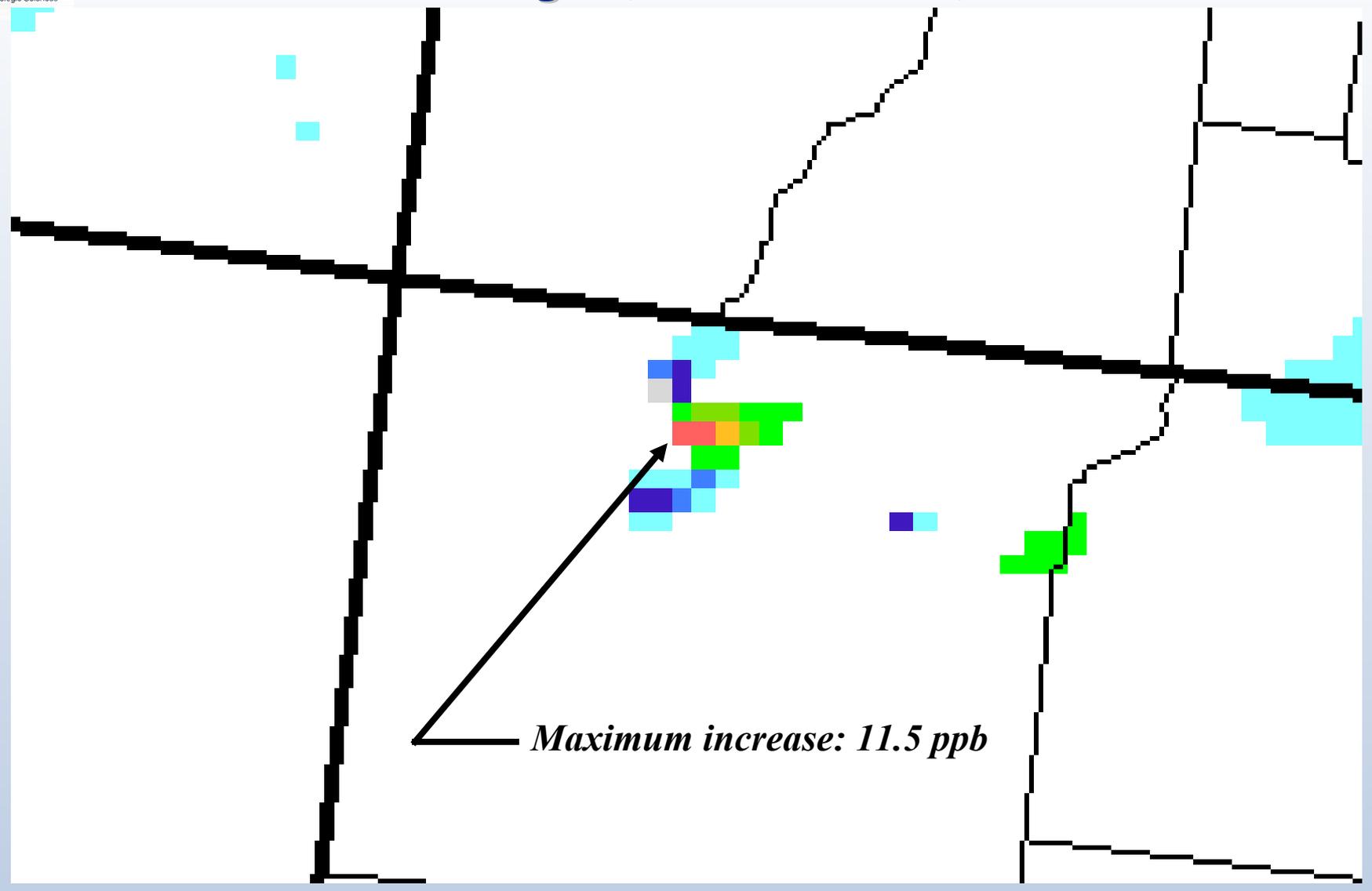
8-hr Ozone Change ('07 minus '02): 6 June



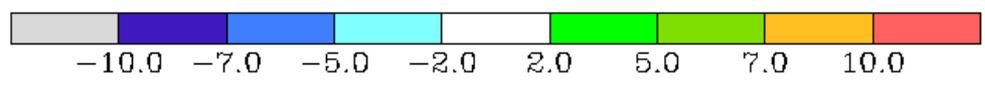
8-hr Ozone Change ('07 minus '02): 7 June



8-hr Ozone Change ('07 minus '02): 7 June



Maximum increase: 11.5 ppb



Future Year 8-hr Ozone Impacts

Table 1a. Comparison of Base Year and Future Year Daily Maximum 8-hr Ozone (ppb).

Date	Day	Bloomfield				Substation			
		2002 Obs.	2002 Base	2007 Base	Change	2002 Obs.	2002 Base	2007 Base	Change
4-Jun	155	64.3	56.6	56.8	0.2	65.0	53.7	54.0	0.2
5-Jun	156	80.6	63.4	63.6	0.2	75.8	61.5	64.1	2.6
6-Jun	157	69.9	64.0	63.6	-0.4	69.6	62.8	62.9	0.1
7-Jun	158	68.6	66.3	66.8	0.5	77.1	62.4	62.7	0.3
8-Jun	159	71.0	60.4	58.9	-1.5	76.8	58.3	56.9	-1.4
16-Jun	167	71.5	64.8	64.7	-0.1	73.8	63.6	64.0	0.4
17-Jun	168	74.3	66.7	66.8	0.1	80.4	64.7	64.9	0.2
18-Jun	169	73.5	68.2	68.1	-0.1	75.1	67.3	67.0	-0.3
19-Jun	170	76.8	68.3	65.0	-3.2	74.6	65.0	62.5	-2.5
30-Jun	181	63.0	64.8	72.1	7.3	64.3	64.3	72.2	7.9
1-Jul	182	61.4	55.6	55.7	0.1	64.4	55.3	54.3	-1.0
2-Jul	183	78.8	62.8	62.8	-0.1	72.3	58.9	58.7	-0.2
16-Jul	197	68.1	60.1	57.8	-2.3	70.3	60.8	59.0	-1.9
17-Jul	198	74.5	65.2	62.3	-2.9	74.3	64.4	62.8	-1.6
18-Jul	199	79.2	63.3	59.5	-3.8	67.1	57.8	55.7	-2.0
Average		71.7	63.4	63.0	-0.4	72.0	61.4	61.4	0.1
Maximum		80.6	68.3	72.1	7.3	80.4	67.3	72.2	7.9

For Consistency with the CAMx Model Performance Evaluation, Base Year 2002 and Future Year 2007 Ozone Statistics Presented in this Table are Derived from "Best" Modeled Values in the 7 x 7 Neighborhood Arrays.

Future Year 8-hr Ozone Impacts

Table 1b. Comparison of Base Year and Future Year Daily Maximum 8-hr Ozone (ppb).

Date	Day	Ignacio				Bondad			
		2002 Obs.	2002 Base	2007 Base	Change	2002 Obs.	2002 Base	2007 Base	Change
4-Jun	155	54.9	54.8	58.1	3.2	45.5	51.9	56.9	5.0
5-Jun	156	60.9	60.8	60.8	0.0	50.8	54.8	60.9	6.1
6-Jun	157	61.3	64.4	66.1	1.6	51.5	61.4	66.1	4.6
7-Jun	158	53.9	65.9	68.5	2.7	44.5	63.1	67.8	4.7
8-Jun	159	61.0	62.2	63.7	1.5	48.9	60.5	62.6	2.1
16-Jun	167	56.9	58.9	62.2	3.3	53.5	57.8	61.7	4.0
17-Jun	168	61.8	63.1	66.2	3.1	60.4	61.4	66.2	4.8
18-Jun	169	60.5	65.4	68.3	3.0	57.1	63.5	68.3	4.8
19-Jun	170	60.5	62.3	69.2	6.9	58.3	60.2	67.7	7.4
30-Jun	181	54.8	58.4	63.1	4.7	45.6	58.2	64.6	6.4
1-Jul	182	56.8	53.5	52.7	-0.9	47.8	49.0	53.3	4.3
2-Jul	183	56.1	54.9	53.8	-1.1	49.8	51.0	56.8	5.8
16-Jul	197	50.8	51.7	56.7	5.0	46.1	53.7	59.1	5.4
17-Jul	198	54.0	54.2	59.4	5.2	49.3	56.2	60.6	4.5
18-Jul	199	60.4	60.4	60.2	-0.2	53.8	59.7	61.3	1.6
Average		57.6	59.4	61.9	2.5	50.8	57.5	62.3	4.8
Maximum		61.8	65.9	69.2	6.9	60.4	63.5	68.3	7.4

For Consistency with the CAMx Model Performance Evaluation, Base Year 2002 and Future Year 2007 Ozone Statistics Presented in this Table are Derived from "Best" Modeled Values in the 7 x 7 Neighborhood Arrays.

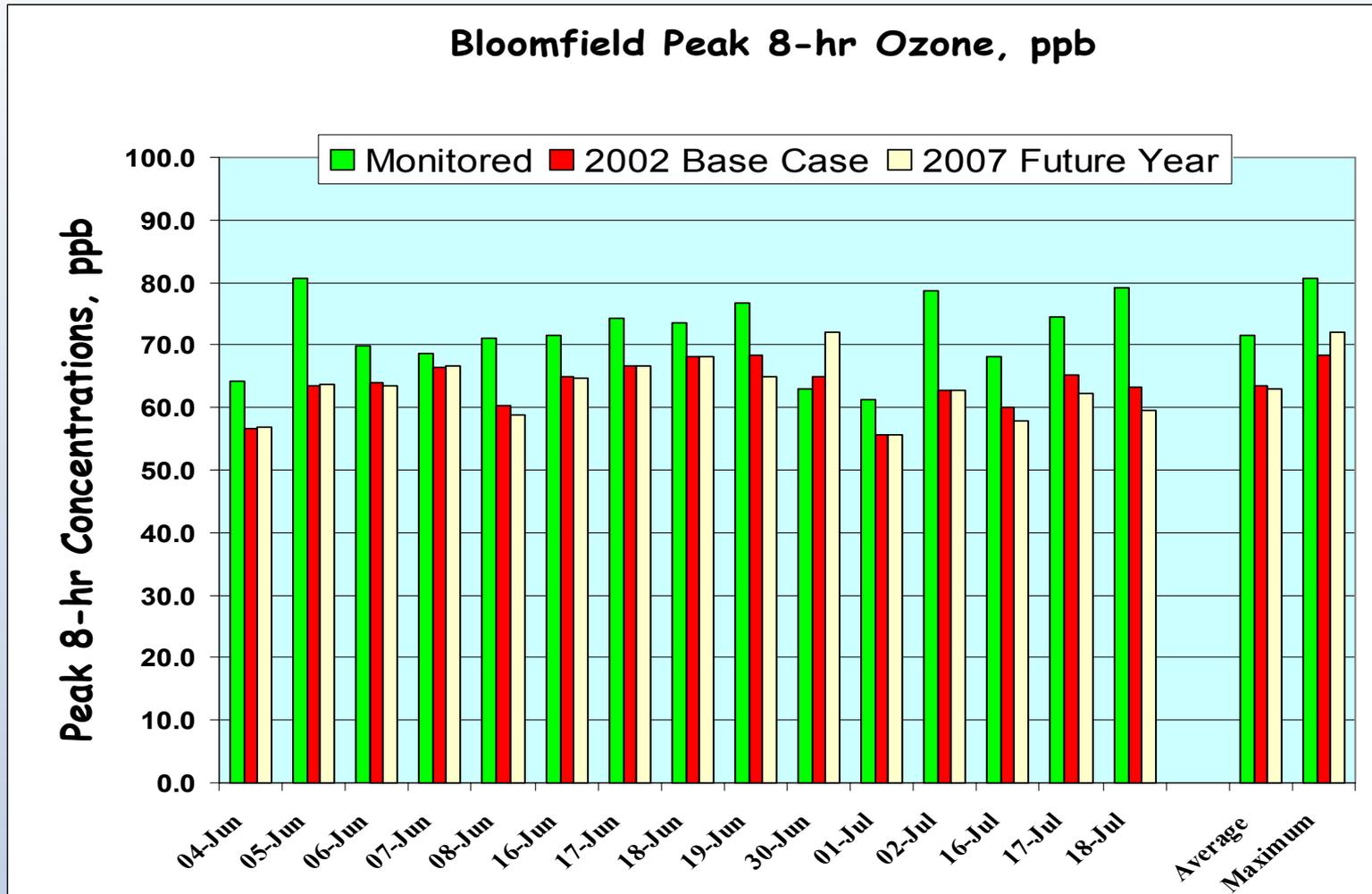
Future Year 8-hr Ozone Impacts

Table 1c. Comparison of Base Year and Future Year Daily Maximum 8-hr Ozone (ppb).

Date	Day	Mesa Verde				Summary of Residuals			
		2002 Obs.	2002 Base	2007 Base	Change	Bloomfield	Substation	Ignacio	Bondad
4-Jun	155	63.8	53.6	53.6	0.0	0.2	0.2	3.2	5.0
5-Jun	156	69.3	56.5	56.4	-0.1	0.2	2.6	0.0	6.1
6-Jun	157	68.4	64.9	65.4	0.5	-0.4	0.1	1.6	4.6
7-Jun	158	65.3	64.3	66.8	2.5	0.5	0.3	2.7	4.7
8-Jun	159	69.3	59.3	57.5	-1.8	-1.5	-1.4	1.5	2.1
16-Jun	167	68.6	62.4	63.2	0.8	-0.1	0.4	3.3	4.0
17-Jun	168	70.9	65.7	66.0	0.3	0.1	0.2	3.1	4.8
18-Jun	169	70.9	70.8	71.5	0.7	-0.1	-0.3	3.0	4.8
19-Jun	170	77.5	62.6	61.1	-1.5	-3.2	-2.5	6.9	7.4
30-Jun	181	61.5	61.3	63.8	2.5	7.3	7.9	4.7	6.4
1-Jul	182	60.5	52.7	52.6	-0.1	0.1	-1.0	-0.9	4.3
2-Jul	183	65.1	56.8	56.6	-0.2	-0.1	-0.2	-1.1	5.8
16-Jul	197	67.0	60.2	57.8	-2.5	-2.3	-1.9	5.0	5.4
17-Jul	198	66.0	62.0	61.4	-0.5	-2.9	-1.6	5.2	4.5
18-Jul	199	63.9	63.4	63.2	-0.2	-3.8	-2.0	-0.2	1.6
Average		67.2	61.1	61.1	0.0	-0.4	0.1	2.5	4.8
Maximum		77.5	70.8	71.5	2.5	7.3	7.9	6.9	7.4

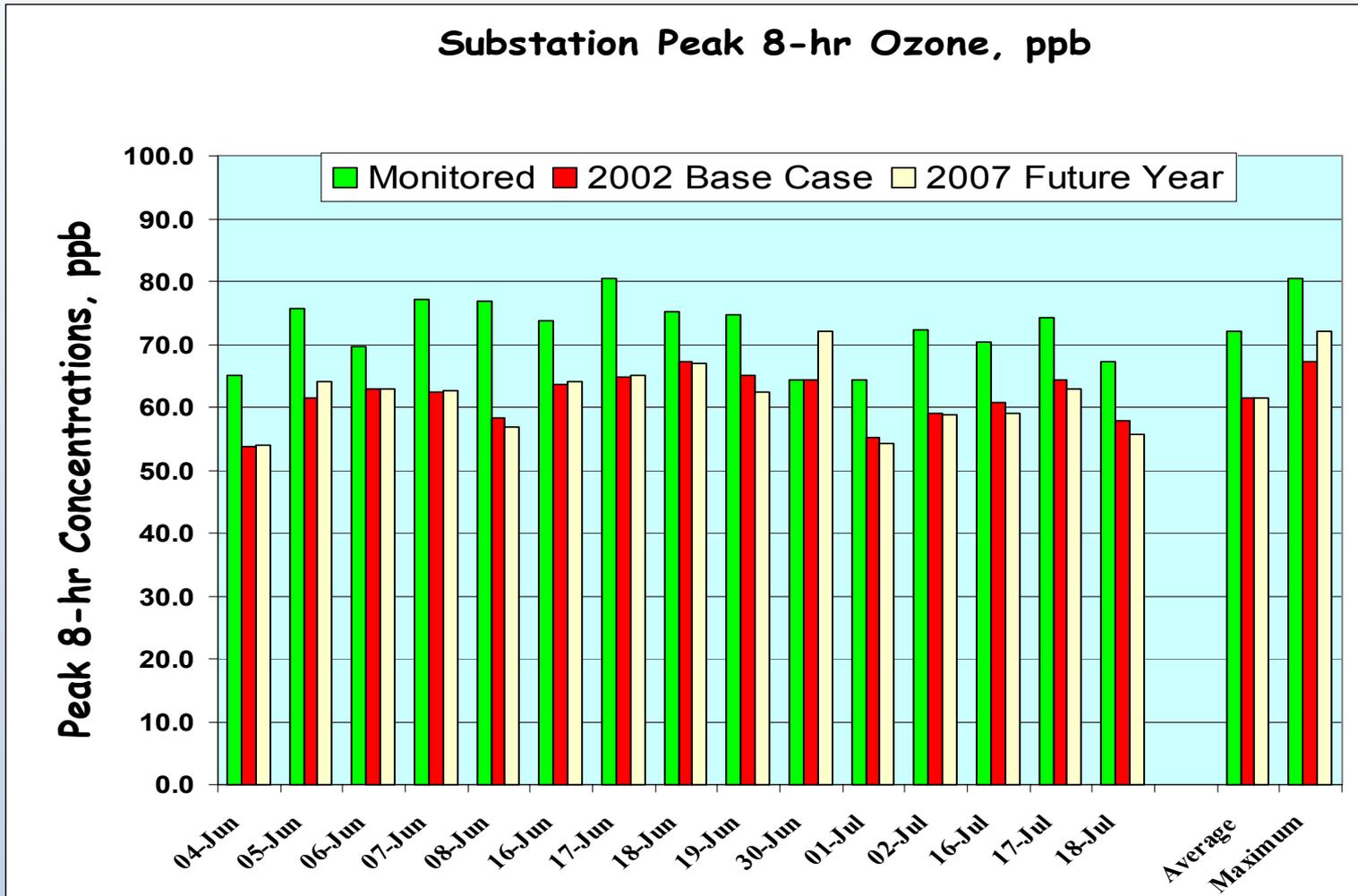
For Consistency with the CAMx Model Performance Evaluation, Base Year 2002 and Future Year 2007 Ozone Statistics Presented in this Table are Derived from "Best" Modeled Values in the 7 x 7 Neighborhood Arrays.

Ozone Impacts at Bloomfield



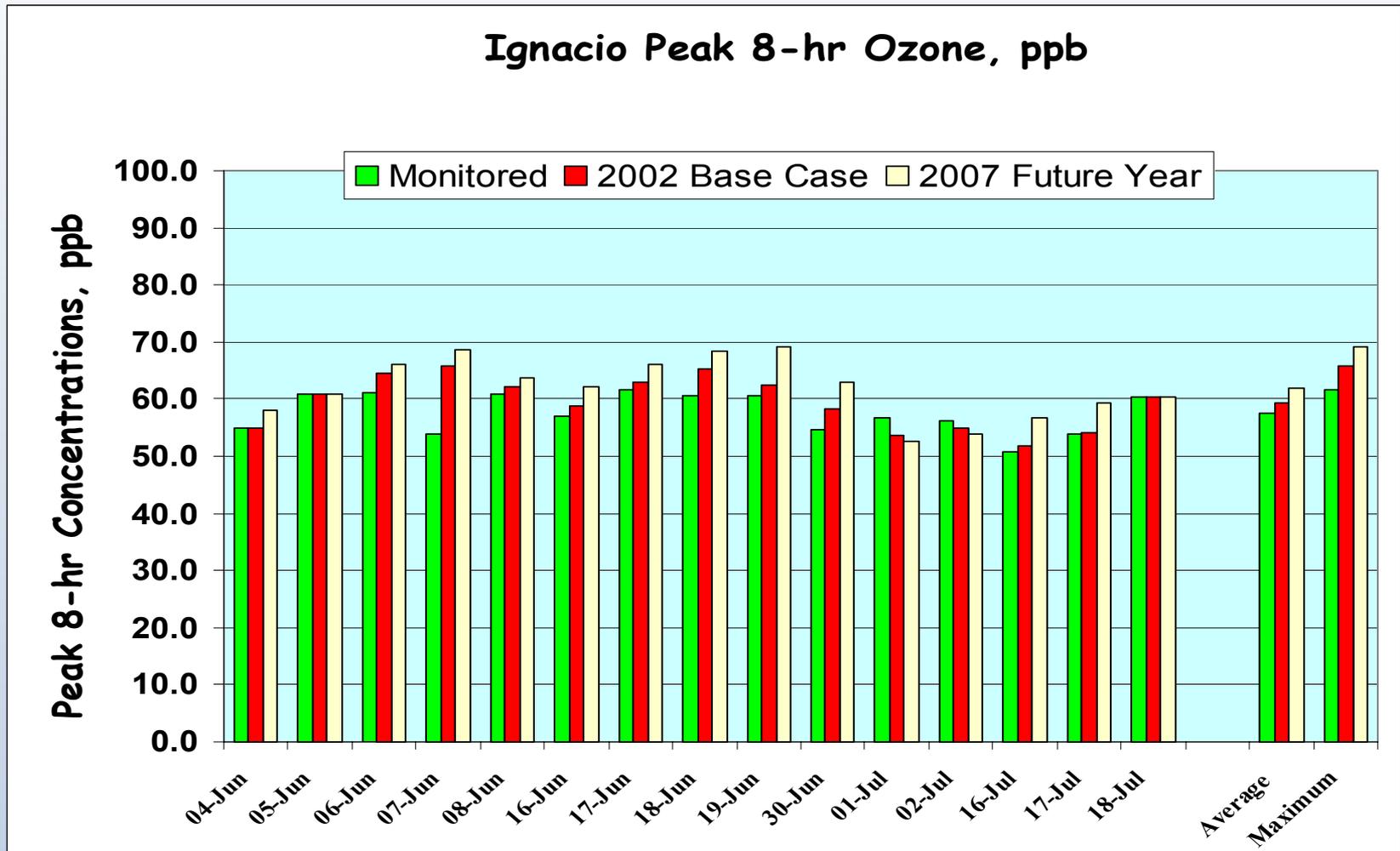
For Consistency with the CAMx Model Performance Evaluation, Base Year 2002 and Future Year 2007 Ozone Peaks Presented in this Figure are Derived from "Best" Modeled Values in the 7 x 7 Neighborhood Arrays.

Ozone Impacts at Substation



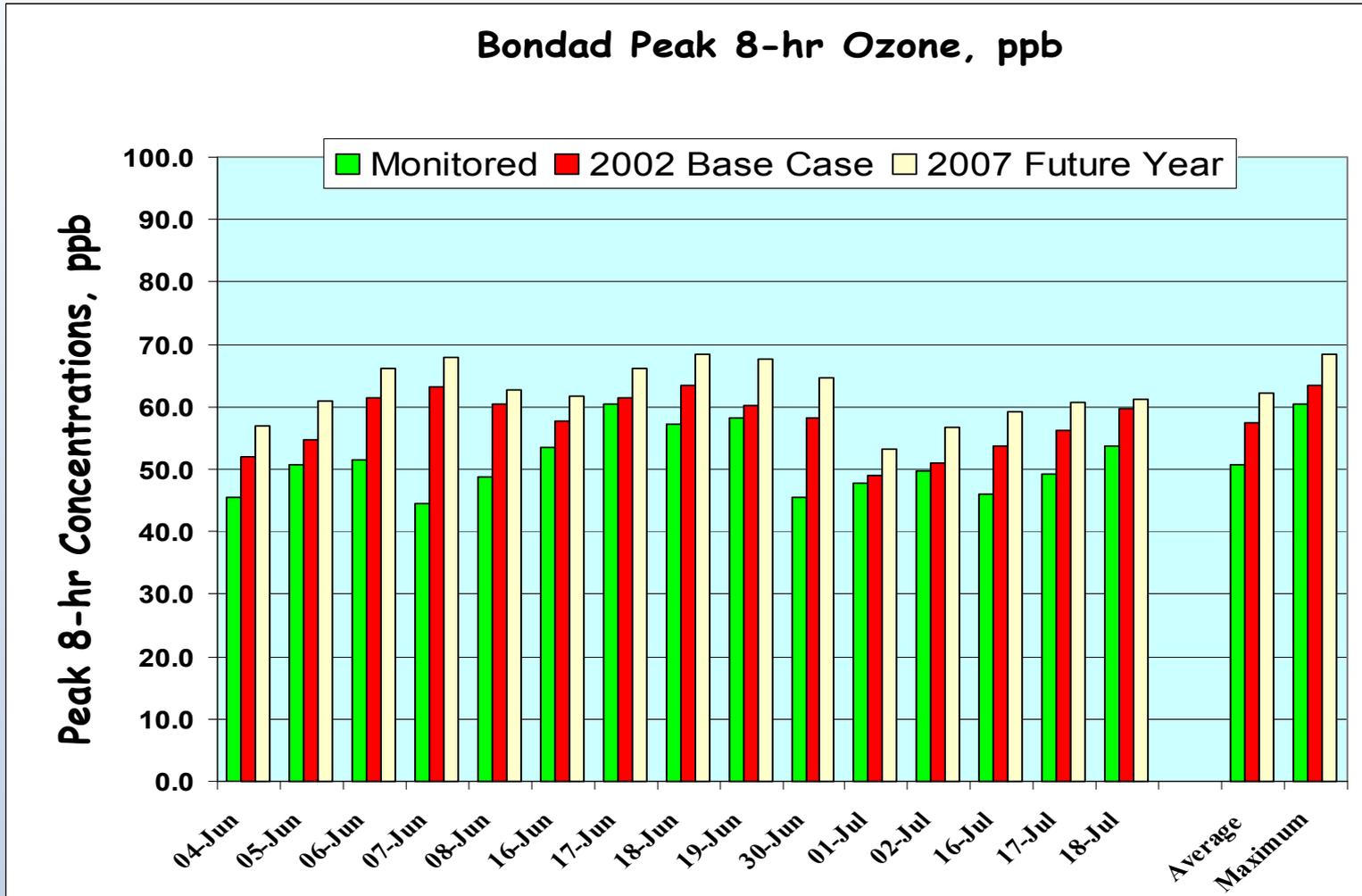
For Consistency with the CAMx Model Performance Evaluation, Base Year 2002 and Future Year 2007 Ozone Peaks Presented in this Figure are Derived from "Best" Modeled Values in the 7 x 7 Neighborhood Arrays.

Ozone Impacts at Ignacio



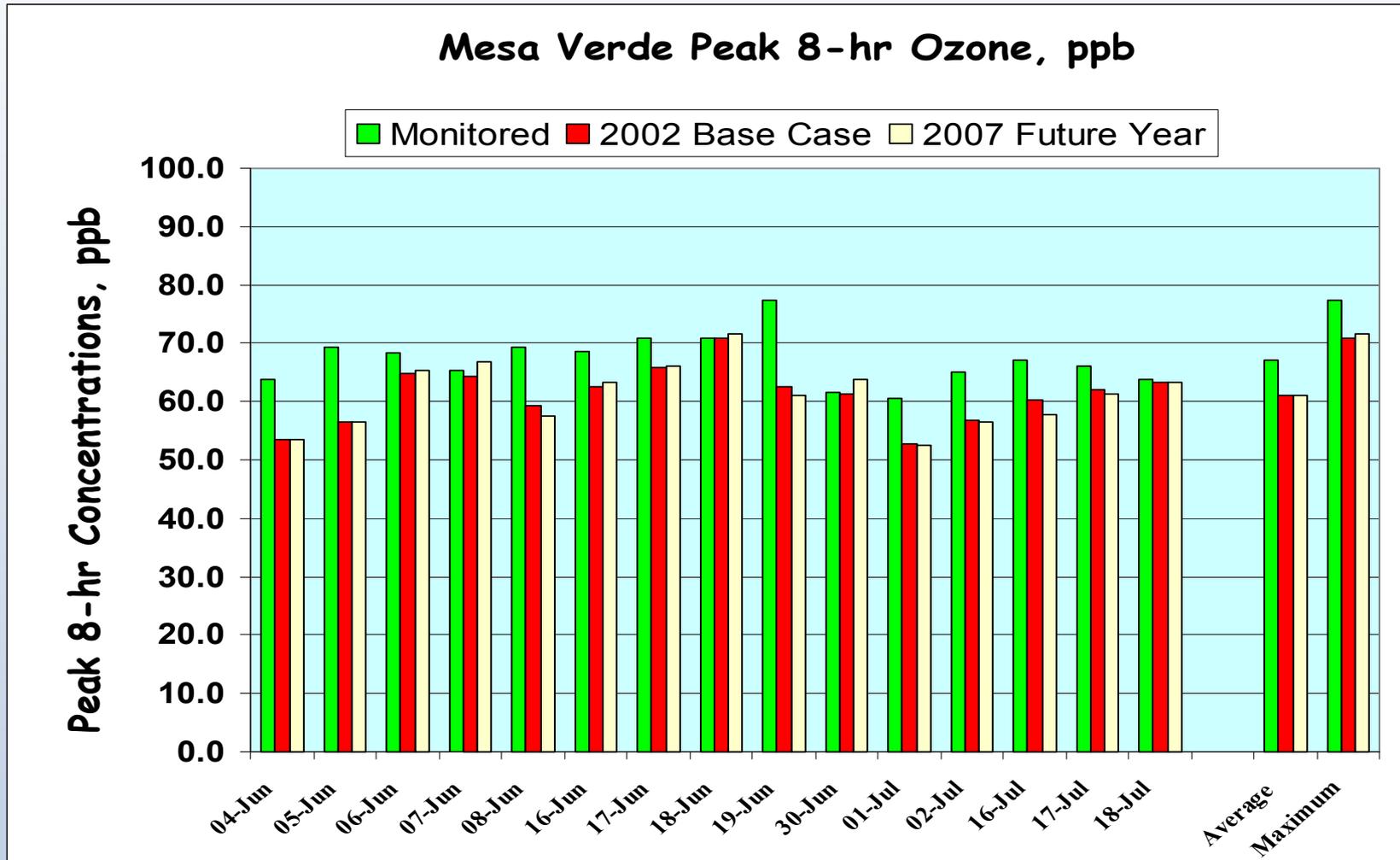
For Consistency with the CAMx Model Performance Evaluation, Base Year 2002 and Future Year 2007 Ozone Peaks Presented in this Figure are Derived from "Best" Modeled Values in the 7 x 7 Neighborhood Arrays.

Ozone Impacts at Bondad



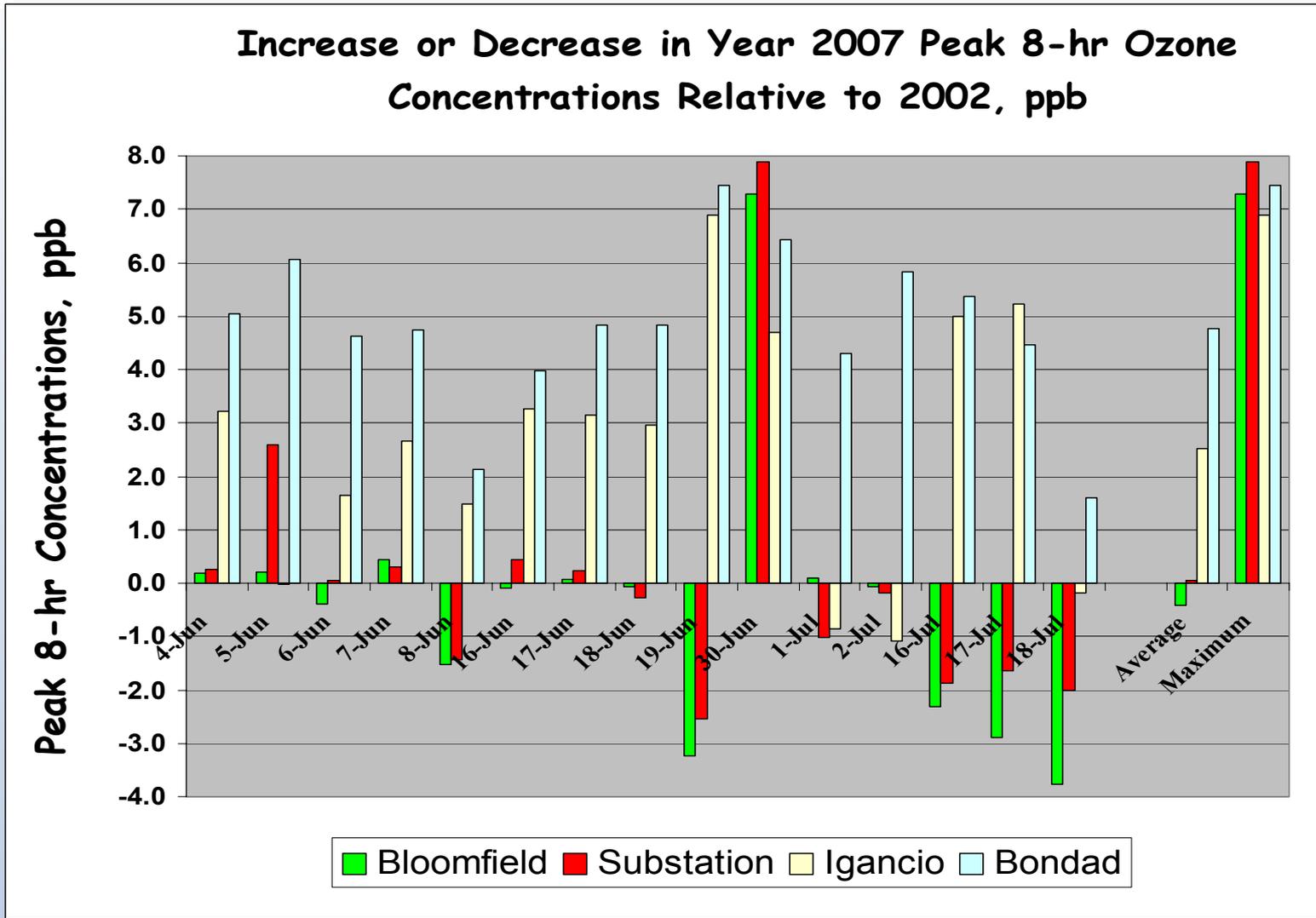
For Consistency with the CAMx Model Performance Evaluation, Base Year 2002 and Future Year 2007 Ozone Peaks Presented in this Figure are Derived from "Best" Modeled Values in the 7 x 7 Neighborhood Arrays.

Ozone Impacts at Mesa Verde



For Consistency with the CAMx Model Performance Evaluation, Base Year 2002 and Future Year 2007 Ozone Peaks Presented in this Figure are Derived from "Best" Modeled Values in the 7 x 7 Neighborhood Arrays.

Change in 8-hr Ozone From 2002 to 2007



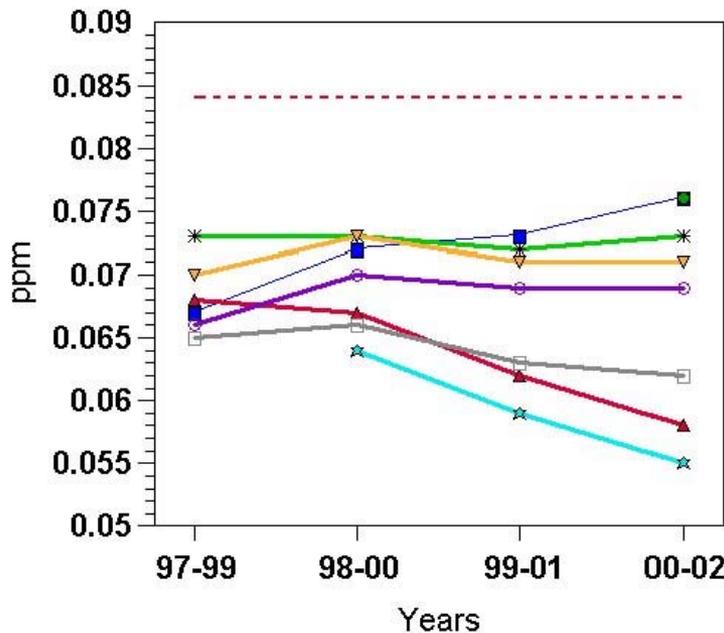
For Consistency with the CAMx Model Performance Evaluation, Base Year 2002 and Future Year 2007 Ozone Peaks Presented in this Figure are Derived from "Best" Modeled Values in the 7 x 7 Neighborhood Arrays.

8-hr Ozone Attainment Demonstration



Trends in 8-hr Ozone Design Values in the San Juan/Four Corners Region

8-hour Ozone Trends
Substation/Bloomfield Sites in San Juan Co., NM
Compared to other Regional Sites
3-year running design values



- | | |
|-----------------|--------------|
| Substation | Grand Canyon |
| Bloomfield | Canyonlands |
| La Plata (7001) | Big Bend |
| La Plata (7003) | NAAQS |
| Mesa Verde | |

2001-2003 Design Values:

Substation = 74.7 ppb

Bloomfield = 74.3 ppb

2000-2002 Design Values for Substation & Bloomfield = 0.076 ppm
Substation ozone monitoring began 5/8/97
Bloomfield ozone monitoring began 6/7/2000

EPA 8-hr Ozone Attainment Test

Future Year Max 8-hr Ozone

< 85 ppb ATTAINMENT

≥ 85 ppb NOT ATTAINMENT

Future Year Ozone = D.V. x RRF

D.V. = Avg. of 4th highest 8-hr O₃ over three most recent years

RRF (Relative Reduction Factor)

$$= \frac{\textit{Future Year (2007) Modeled 8-hr Ozone}}{\textit{Base Year (2002) Modeled 8-hr Ozone}}$$

So, model results used in a relative sense.

Alternative Methods of Selecting Modeled Ozone Concentrations

- **Alternative methods for extracting peak 1-hr or 8-hr values:**
 - ▶ Use model prediction in grid cell containing monitor
 - ▶ Use 4-cell weighted average of four cells nearest to and including monitor
 - ▶ Use cell containing closest (best) predicted value to monitored value
 - ▶ Use average of all cells in the 7 x 7 array of neighborhood monitors
 - ▶ Use highest prediction in any cell in the 7 x 7 array of neighborhood monitors
- **EPA attainment demonstration recommends latter (highest) method**
- **Use of ‘highest’ value biases model performance evaluation results**
- **CAMx model evaluation used ‘best’ prediction in 7 x 7 array**

Case Study: 30 Jun '02 8-hr Ozone at Bloomfield Monitor

Table 1. Alternative 8-hr Ozone Predictions: Bloomfield, 30 Jun '02

Bloomfield Monitor	Maximum	Maximum	Bias, ppb	Accuracy
Data Extraction Method	Observed	Predicted		of Peak, %
Cell Containing Monitor	63.0	63.79	0.79	1.2%
Best Cell in 7 x 7 Array	63.0	64.84	1.84	2.9%
4-Cell Weighted Average	63.0	66.57	3.57	5.7%
Average in 7 x 7 Array	63.0	68.01	5.01	8.0%
Highest in 7 x 7 Array	63.0	71.44	8.44	13.4%

Current 8-hr Design Values

D.V. = Avg. of 4th highest 8-hr O₃ over three most recent years (2001-2003)

For Substation, DV = (74 + 75 + 75) = 74.7 ppb

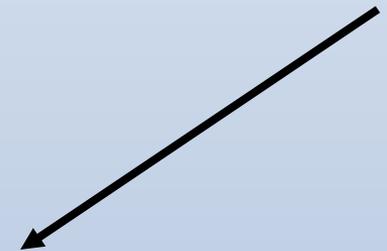
For Bloomfield, DV = (74 + 76 + 73) = 74.3 ppb

Modeled 2007 8-hr Design Values

Table 2a. Eight-Hour Design Value Projections for 2007 for the Four San Juan EAC Episodes																			
Monitoring Location	Obs DV	04-Jun	05-Jun	06-Jun	07-Jun	08-Jun	16-Jun	17-Jun	18-Jun	19-Jun	30-Jun	01-Jul	02-Jul	16-Jul	17-Jul	18-Jul	AVG	2007	
		155	156	157	158	159	167	168	169	170	181	182	183	197	198	199	All	DV	
Measured Daily Maximum 8-hr Ozone Concentration (ppb)																			
Bloomfield	74.3	64.25	80.63	69.88	68.63	71.00	71.50	74.25	73.50	76.75	63.00	61.38	78.75	68.13	74.50	79.17	71.69		
Substation	74.7	65.00	75.75	69.63	77.14	76.75	73.75	80.38	75.13	74.63	64.25	64.38	72.25	70.25	74.25	67.13	72.04		
Ignacio	75.0	54.88	60.88	61.25	53.88	61.00	56.88	61.75	60.50	60.50	54.75	56.75	56.13	50.75	54.00	60.38	57.62		
Bondad	75.0	45.50	50.75	51.50	44.50	48.88	53.50	60.38	57.13	58.25	45.63	47.75	49.75	46.13	49.25	53.75	50.84		
Mesa Verde	69.0	63.75	69.25	68.38	65.25	69.25	68.63	70.88	70.88	77.50	61.50	60.50	65.13	67.00	66.00	63.88	67.19		
2002 Modeled Daily Maximum 8-hr Ozone in 7 x 7 Cell Neighborhood (ppb)																			
Bloomfield	74.3	56.59	63.41	63.97	66.32	60.39	64.83	66.72	68.17	68.26	71.44	66.62	62.82	60.12	65.18	63.27	64.54		
Substation	74.7	53.71	61.55	62.84	62.43	58.34	63.55	64.71	67.27	64.99	68.66	55.29	58.92	60.83	64.45	57.77	61.69		
Ignacio	75.0	57.84	61.49	67.38	69.15	65.26	63.69	67.03	69.96	70.13	63.05	53.51	54.89	57.96	61.63	63.13	63.07		
Bondad	75.0	56.43	61.48	66.62	68.26	64.07	63.06	66.82	69.70	68.71	64.56	54.00	57.95	60.35	62.66	64.77	63.30		
Mesa Verde	69.0	53.56	56.50	64.89	66.56	59.28	62.45	65.71	72.53	62.61	62.42	52.67	56.84	60.22	61.97	63.44	61.44		
2007 Modeled Daily Maximum 8-hr Ozone in 7 x 7 Cell Neighborhood (ppb)																			
Bloomfield	74.3	56.77	63.62	63.58	66.77	58.86	64.75	66.78	68.10	65.02	72.12	55.72	62.75	57.80	62.29	59.51	62.96		
Substation	74.7	53.96	64.14	62.89	62.74	56.91	64.00	64.94	67.00	62.46	72.16	54.27	58.74	58.97	62.81	55.75	61.45		
Ignacio	75.0	58.07	60.81	66.06	68.53	63.69	63.18	66.19	68.33	69.21	63.06	52.65	53.79	56.71	59.37	60.24	61.99		
Bondad	75.0	56.94	60.90	66.05	67.85	62.58	61.74	66.19	68.30	67.65	64.64	53.26	56.77	59.10	60.62	61.31	62.26		
Mesa Verde	69.0	53.58	56.43	65.41	66.76	57.52	63.22	66.00	71.52	61.10	63.78	52.59	56.65	57.77	61.42	63.22	61.13		
2007-2002 Relative Reduction Factors By Station and Day																			
Bloomfield	74.3	1.003	1.003	0.994	1.007	0.975	0.999	1.001	0.999	0.953	1.010	0.836	0.999	0.961	0.956	0.941	0.976	72.49	
Substation	74.7	1.005	1.042	1.001	1.005	0.975	1.007	1.004	0.996	0.961	1.051	0.982	0.997	0.969	0.975	0.965	0.996	74.37	
Ignacio	75.0	1.004	0.989	0.980	0.991	0.976	0.992	0.987	0.977	0.987	1.000	0.984	0.980	0.978	0.963	0.954	0.983	73.72	
Bondad	75.0	1.009	0.991	0.991	0.994	0.977	0.979	0.991	0.980	0.985	1.001	0.986	0.980	0.979	0.967	0.947	0.984	73.78	
Mesa Verde	69.0	1.000	0.999	1.008	1.003	0.970	1.012	1.004	0.986	0.976	1.022	0.998	0.997	0.959	0.991	0.997	0.995	68.65	

“Highest”
Values in 7 x 7
Neighborhood
Array Used in
Computing the
RRFs

Monitoring Location	Obs DV	AVG RRF	2007 DV
Bloomfield	74.3	0.976	72.49
Substation	74.7	0.996	74.37
Ignacio	75.0	0.983	73.72
Bondad	75.0	0.984	73.78
Mesa Verde	69.0	0.995	68.65



Weight of Evidence Analyses

- EPA Draft 8-hr Ozone Guidance (EPA, 1999)
 - ▶ Modeled max 8-hr ozone Design Value < 90 ppb
 - ▶ Air Quality Modeling Analysis
 - Change in grid-hours with ozone > 84 ppb
 - Number grid cells > 84 ppb
 - Change in ppb-hr with ozone > 84 ppb
 - ▶ Air Quality and Emission Trends
 - Extrapolation of DV to attainment year
 - Emission Trends
 - ▶ Observation Based Models (OBM)
 - Not quantitative, support VOC/NO_x selection

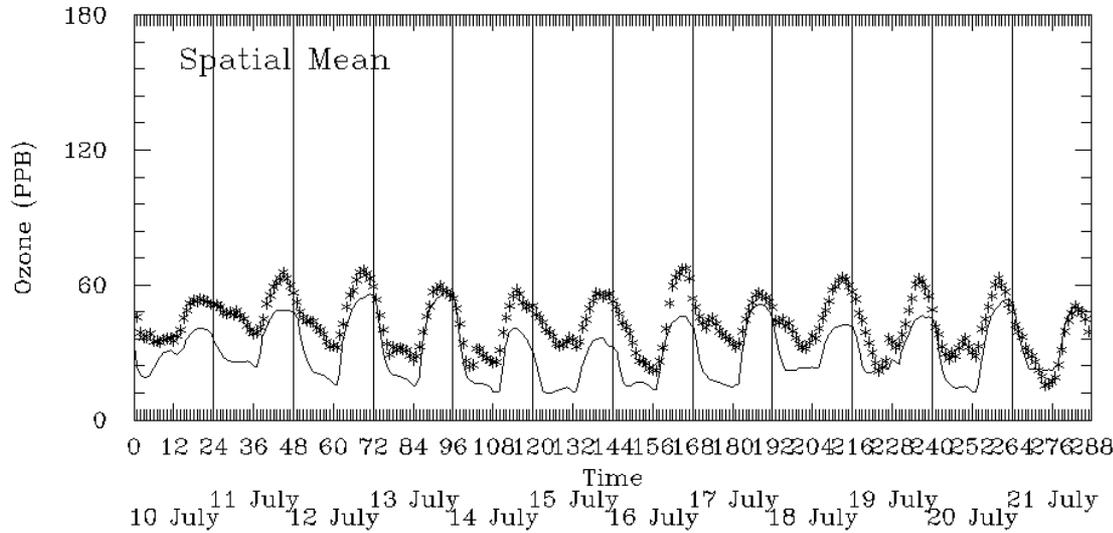
Weight of Evidence analyses not needed since the highest modeled grid cell in 2007 (72.2 ppb) is well below EPA's 84.0 ppb cutoff

Corroborative Modeling Over the San Juan/Four Corners Region

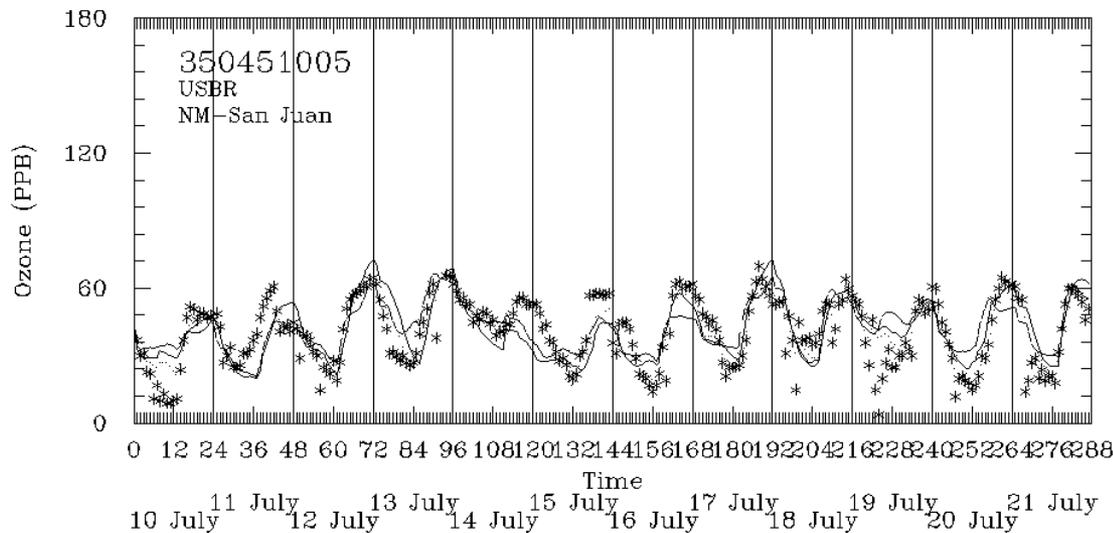
- **CMAQ Model Simulation of 13-21 July '99 Ozone Episode Across Full U.S**
 - EPA guidance encourages use of corroborative models in weight of evidence investigations
 - Alternative model (CMAQ) uses:
 - Same meteorological model (MM5)
 - Same or similar national emissions inventories
 - Same or similar modeling science as CAMx

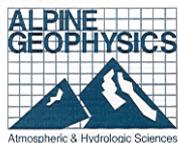
CMAQ Results for 10-21 July '99 Episode over the U.S. at 36 km Horizontal Resolution: Four Corners Region Results

New Mexico Spatial Mean



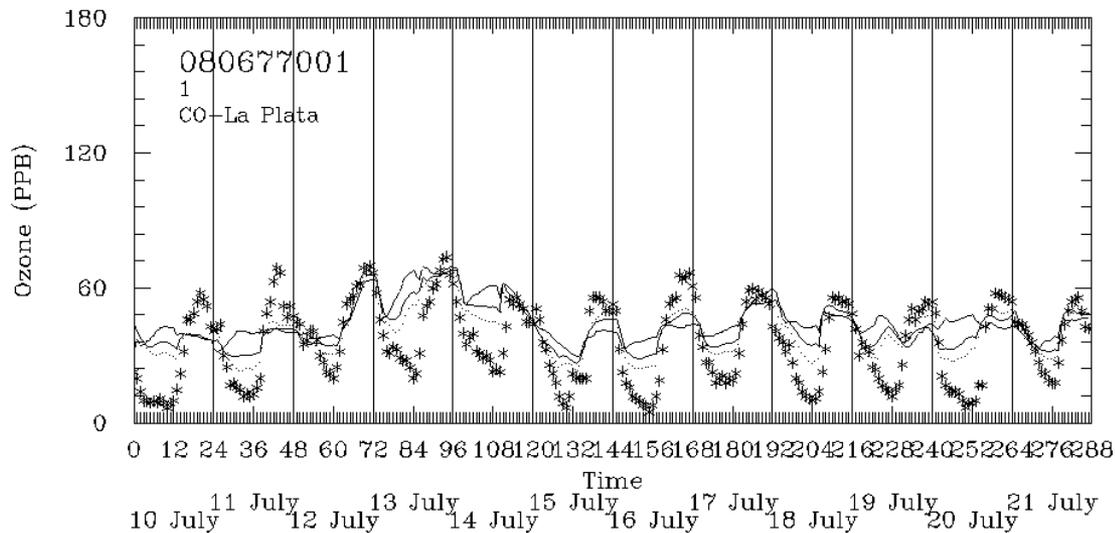
Substation:



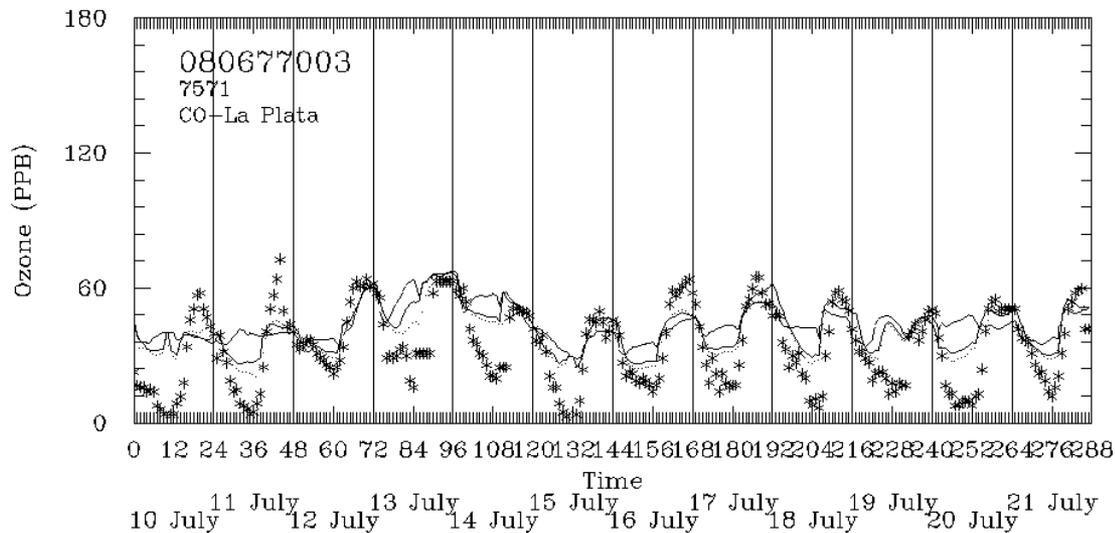


CMAQ Results for 10-21 July '99 Episode over the U.S. at 36 km Horizontal Resolution: Four Corners Region Results

Ignacio:

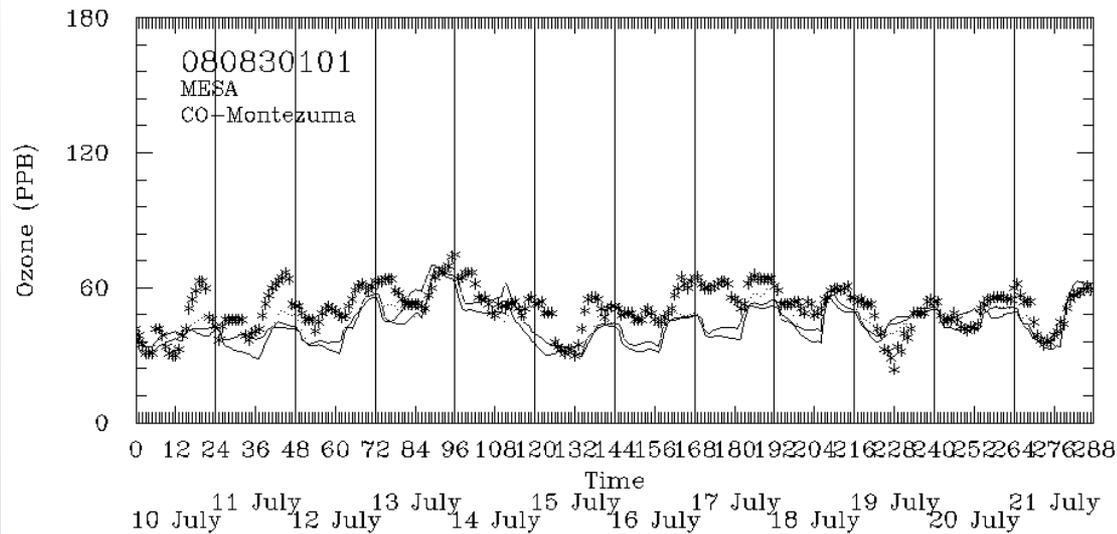


Bondad:



Spatial Mean Ozone Time Series: CMAQ 36 km

Mesa Verde:



Corroborative Model Findings

- **CMAQ confirms systematic ozone underestimation across western U.S. and Four Corners Region**
- **CMAQ also tends to ‘clip’ daily ozone peaks and minima**
- **Corroborative modeling confirms potential systematic underestimation in source emissions across western U.S. and possibly the Four Corners Region**

Next Steps- Scenario Modeling

- **Define ‘Maintenance for Growth’ Modeling Scenario**
- **Define Future Year Emissions Control Scenario(s)**
- **Define Additional Modeling Scenarios of Interest**
 - ▶ **Ozone source apportionment runs**
 - ▶ **Model sensitivity to future year emissions estimate uncertainties**
 - ▶ **Other**
- **Prepare Final Report**

Future Research Suggestions

- **Emissions Inventory:**

- ▶ **Incorporation of additional local point source data**
- ▶ **Incorporation of local on-road mobile source data (Four Corners area are likely not representative of national defaults used in MOBILE6.2)**
- ▶ **Inclusion of day-specific activity and temperature adjustments**
- ▶ **Refined inclusion of oil and gas sources in surrounding states**

- **Air Quality Modeling**

- ▶ **Additional source apportionment analyses to identify most likely source regions and source categories contributing to peak ozone**
- ▶ **Model sensitivity/uncertainty analysis to examine role of emissions and meteorological uncertainties in modeled results**